

Cross-border Patenting, Globalization, and Development[‡]

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Abstract

We build a quantitative model that captures the relationships between cross-border patenting, globalization, and development. Our theory delivers a ‘structural gravity’ equation for cross-border patents. To test the model’s predictions, we compile a new dataset that tracks patents within and between countries and industries over time. The econometric analysis reveals a strong, positive impact of policy and globalization on cross-border patent flows between 1995 and 2018, especially from North to South. A counterfactual analysis shows these North-to-South flows benefited both regions, with larger gains in the South, especially after 2000, thus reducing global income inequality.

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1 Introduction

In recent decades, the rise of globalization has led to a significant increase in cross-border patenting as companies seek to protect their innovations in international markets. Cross-border patenting can foster development by stimulating economic activity, facilitating technology transfer, and attracting foreign direct investment (FDI).

“Today, FDI is not only about capital, but also –and more important– about technology and know-how, [...] International patterns of production are leading to new forms of cross-border investment, in which foreign investors share their intangible assets such as know-how or brands in conjunction with local capital or tangible assets of domestic investors.” (The World Bank, 2015)

However, cross-border patenting can also have negative implications if strong patent protection grants excessive monopoly power to innovators, potentially widening the technological gap between developed and developing nations and exacerbating income inequality. The extent of cross-border patenting is heavily influenced by the strength of intellectual property rights (IPR) enforcement in the target countries. Robust IPR protection encourages companies to file patents and disclose their inventions without fear of imitation or infringement, while weak IPR regimes may discourage cross-border patenting and limit the potential for technology transfer and economic growth. This paper explores the intersection of cross-border patenting, globalization, and development, investigating the drivers behind the increase in international patent filings and examining the conditions under which this trend may contribute to economic development.

Against this backdrop, we make the following contributions. First, we build a new comprehensive database that tracks cross-border patenting flows and citations across and within countries and industries from 1980 to 2019. Second, from a methodological perspective, we develop a model that delivers a structural gravity equation for cross-border patents, which resembles familiar and intuitive gravity models from physics and trade. Third, on the estimation front, we translate our structural model into an estimating equation for cross-border patents by capitalizing on established developments in the empirical

gravity literature on trade, migration, and FDI. Fourth, from a policy perspective, we offer a series of estimates of the effects of various policy determinants on the cross-border patent flows, as well as estimates of the effects of globalization, which we define as trends that go beyond observable policies.¹ Finally, we use our theory and partial estimates to show that the exchange of cross-border patents has been mutually beneficial to developed and developing countries but has benefited developing countries disproportionately more, especially after 2000, thus decreasing real income inequality in the world.

Our novel *International Patent and Citations across Sectors* (INPACT-S) database tracks cross-border and domestic patent flows across industries over four decades.² INPACT-S is more comprehensive than other publicly available datasets along five key dimensions: (i) It encompasses a wider array of patent authorities, offering a full view of global patent activity; (ii) it provides industry-specific bilateral data, allowing to do sectoral analysis; (iii) it captures a greater number of patent applications through imputation methods; (iv) it includes comprehensive data on cross-country and cross-sector citation data; and (v) it includes consistently constructed data on cross-border and *domestic* patents. The domestic dimension of INPACT-S is crucial for our analysis, as it enables us to obtain estimates of the effects of globalization, which go beyond policy and which cannot be identified with data on cross-border patents only.³

We describe in detail the methods that we use to construct INPACT-S, and we highlight the main features of our dataset in Section 2, where we also devote a subsection to comparing INPACT-S with related datasets. We find that, between 1995 and 2018, Europe and North America have been the traditional centers of innovation, but Asia has emerged as a popular destination for patent applications and a leader in innovation. Countries like China, Japan, and Korea have become major players in the global innovation landscape. Cross-border patenting has experienced faster growth compared

¹On the policy front, we examine the role of trade agreements that require increasing protection of IPR, which has been a key topic of discussion in multilateral trade negotiations since the World Trade Organization (WTO) Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS).

²The INPACT-S dataset is available upon request by filling this [questionnaire](#).

³In combination with cross-border patents, the use of domestic patents offers a series of additional benefits for identification, e.g., of the effects of non-discriminatory policies that may target international patenting or, more broadly, any country-specific policy or characteristic that may impact cross-border patents and domestic patents differentially.

to domestic applications, with China being an exception, showcasing an unprecedented surge in domestic patents. Most cross-border patents are from ‘North’ to ‘South’ (542% increase).⁴ The concentration of patents is particularly notable in the fields of Chemicals, Computers, and Medical Equipment.

Motivated by the key patterns that we observe in the data, we build a quantitative multi-country model of cross-border patenting. Innovators invest resources to create new ideas, which serve as blueprints for producing new intermediate goods. Adopters can use an exogenous fraction of these ideas to produce intermediate goods, capturing the concept of diffusion. Due to imperfect enforcement of IPR, innovators apply for patent protection to receive a return for their innovation from the adopters who use the technology. Patenting offers protection to innovators from imitation, but it is a costly activity. The number of patented technologies depends on the value of an innovation, the probability of imitation, and the cost of patenting. The value of innovation, in turn, depends on how profitable the adopter is at commercializing products produced with the innovator’s technology, which is influenced by factors such as their size and productivity.⁵

Our model yields a structural gravity equation for international patenting, which guides our empirical analysis. The determinants of bilateral patent flows in our gravity equation include: (i) time-invariant bilateral patent frictions, (ii) time-varying technology diffusion barriers, trade and patent-related policies, (iii) the attractiveness of the destination market, and (iv) the innovation capacity of the source country. The gravity equation for cross-border patenting differs from the gravity equation for trade flows due to the non-rival nature of patents. Unlike trade flows, where exports to one country come at the opportunity cost of not exporting to other markets, the use of a patented invention in one country does not prevent its simultaneous use in others. The outward multilateral resistance term only enters the cross-border patenting system indirectly through trade in intermediate goods. Consequently, the decision to patent in a particular market depends more on factors such as market size, intellectual property protection, and local

⁴The partition into North and South is based on the income classification of the World Bank for 2000.

⁵This process is akin to technology licensing, where innovators grant the use of their idea to adopters in exchange for royalty payments. Imperfect enforcement of IPR will lead to fewer royalty payments.

enforcement potential, rather than the relative barriers to patenting in other markets.

We use our model to investigate the impact of changes in globalization and trade policy on cross-border patenting. Guided by our theory and capitalizing on the rich dimensionality of INPACT-S, we employ established developments from the gravity literature on trade, migration, and FDI to specify an estimating gravity equation for cross-border patents. We estimate our model with the Poisson Pseudo Maximum Likelihood (PPML) estimator, which takes into account zero patent flows and potential heteroskedasticity of our patent data, which may render OLS estimates inconsistent. We also employ a rich set of fixed effects, including source-time and destination-time fixed effects, which absorb all possible country determinants of patent flows, as well as pair fixed effects, which control for all time-invariant determinants of cross-border patents. While our dataset covers the period from 1980 onward, the empirical analysis focuses on the years from 1995 to 2018. This is due to the limited coverage and reliability of the data on cross-border patent flows and other key variables of interest in the earlier years of the sample period.

To highlight several important aspects of our data and identification strategy and to recover some of the parameters that are needed for the quantitative analysis, we develop the estimation analysis in four nested specifications. The first specification, a simple cross-section with standard time-invariant gravity variables and aggregate border effects, provides initial evidence on the factors influencing patent flows. The results reveal that standard gravity variables have significant effects on international patenting, with distance reducing flows, common language strongly increasing flows, and borders presenting large frictions. The second specification allows the border effects to vary across four country-pair income groups, revealing substantial heterogeneity in the frictions affecting different directional flows. The smallest frictions are found between “North” countries and the largest for flows from “South” countries to “North”.

The third specification exploits the full panel dimension, including country-pair fixed effects to control for all observable and unobservable time-invariant bilateral patent frictions, and introduces time-varying border effects to capture the impact of globalization on each bilateral income group over time. The panel data analysis allowing for time-varying

border effects shows that globalization has dramatically increased patenting from “North” to “South” countries during the period studied, with flows growing by around 300%. In other words, globalization and diffusion forces can explain about 55% of the increase in cross-border patenting from “North” to “South” in the data. In contrast, globalization has not significantly benefited cross-border patenting originating from the “South”.

Fourth, in addition to allowing for heterogeneous globalization effects, our main specification introduces a series of policy variables, including regional trade agreements (RTAs), which may or may not include technology provisions, the Trade-Related Aspects of Intellectual Property Rights (TRIPS) agreement, and the Patent Cooperation Treaty (PCT). Similar to the analysis of the effects of globalization, we also allow for heterogeneous effects of each of the policy variables across the four bilateral income groups. We draw three main conclusions based on this analysis: (i) Policy efforts have been effective to promote cross-border patent flows; (ii) the policy effects have been heterogeneous across policies (e.g., for RTAs vs. PCT) and depending on the direction of patent flows (e.g., for “North” to “North” vs. “South to North”); and (iii) the policy covariates in our econometric model fully account for the change in cross-border patent flows across all groups, except for “North” to “South”.

We conclude the estimation analysis with a battery of robustness experiments to test the sensitivity of our main findings and to highlight some additional dimensions of our new database. Three main findings stand out from this analysis. First, overall, our main conclusions regarding the impact of policy and globalization on cross-border patent flows are reinforced by the additional robustness experiments. Second, we find that some of the effects of the “standard” gravity variables, e.g., distance and common official language, are similar for trade flows and cross-border patents. However, we also find opposing effects for other gravity variables, e.g., contiguity and colonial relationships. While not important for our current purposes, we found these results interesting. Finally, our sectoral analysis (i) revealed heterogeneous effects, implying that sound policy analysis of the determinants of cross-border patents should be performed at a disaggregated level, and (ii) reinforced the message that, for RTAs to facilitate cross-patenting between rich and poor countries,

the agreements must contain specific chapters on IPR and innovation.

Armed with the partial estimates, we quantify our model to answer two questions: “What would have been the trajectory of cross-border patenting from North to South between 1995 and 2018 if the globalization trends that we estimated had remained at their 1995 levels?” and “What are the implications for income per capita differences?” For simplicity, and consistent with our empirical results, we partition the world into two groups—North and South—and focus on the impact of globalization on patent flows from North to South. To answer these questions, we start by calibrating the model using data on cross-border patenting flows, R&D intensity, and bilateral trade flows. Our model, though not calibrated with royalty payment data, can replicate the evolution of royalty flows from developing to developed countries between 1995 and 2018. This close match serves as external validation for the model. Then, we study the effect of globalization on cross-border patenting, innovation and inequality.

We draw the following main conclusions based on our counterfactual analysis. First, in the absence of the globalization effects that we estimated, cross-border patenting would have been 38% lower on average between 1995 and 2018. Second, both North and South have gained from the transfer of patents across international borders. However, the gains for South were larger, especially after the 2000s, implying that cross-border patenting has led to a decrease in the real income gap between the poor and the rich countries in the world. Notably, when we account for policy changes in addition to globalization and diffusion forces, we find that income inequality between South and North would have decreased by less than what would have been expected based on globalization and diffusion forces alone, as policy changes have disproportionately benefited North countries.

Related Literature. This paper is related to several strands of literature. First, it is related to studies on the connection between IPR, patents, and development (Helpman, 1993; Lai, 1998; Lai and Qiu, 2003; Kwan and Lai, 2003; Yang and Maskus, 2001; Branstetter et al., 2007, 2011; Tanaka and Iwaisako, 2014; Diwan and Rodrik, 1991). While some research finds stronger patent protection boosts innovation in developed nations at the expense of developing ones (Helpman, 1993; Grossman and Lai, 2004), others

find that strong IP protection in developing countries can increase growth and development (Kwan and Lai, 2003). Hoekman and Saggi (2007) find in a theoretical framework that North and South trade agreements with technology provisions can be beneficial to the South if it has reached a certain level of IP protection. Bond and Saggi (2020) develop a North and South model to study the South's incentive for patent protection. Santacreu (2022) finds that improvements of IP that are associated with trade agreements have a positive impact on technology transfers from North to South through licensing. Hémous et al. (2023) study, quantitatively, optimal patent policy in the global economy. Our paper complements Hémous et al. (2023) by focusing on the impact of both diffusion and trade and IP policy on cross-border patenting.

Second, our paper is related to a strand of literature studying the connections between IPR and technology transfer. Maskus (2000) studies the connections between IPR and international trade, innovation, and growth. Keller (2004) studies the impact of international technology diffusion through various channels on innovation, growth, and development. Glass and Saggi (1998) study how technology transfer helps close the technology gap. Santacreu (2022) studies the impact of trade agreements with IP provisions on technology transfer. We contribute to these two strands of literature by performing an empirical exploration of the impact of globalization and IPR reforms that are part of deep trade agreements on cross-border patenting and, hence, knowledge transfer.

Third, it relates to a recent literature studying the role of RTAs with IP provisions on bilateral flows. Martínez-Zarzoso and Chelala (2021) and Arregui and Martínez-Zarzoso (2022) find that better IPRs increase trade in goods, especially high-tech exports from developed to developing countries and international patenting. Santacreu (2022) finds that regional trade agreements with IP provisions have a positive effect on international technology licensing, especially from developed to developing countries. More closely related to our work, Coleman (2022) and Howard, Maskus, and Ridley (2023) explore the impact of trade liberalizing treaties and treaties strengthening IPR on cross-border patent flows. We contribute to the existing literature by investigating the distributional impacts of globalization forces and RTAs with IP provisions on cross-border patenting.

Our approach involves constructing a comprehensive dataset. Additionally, we employ a stylized model as a guide for our empirical analysis. By exploring these effects across various levels of development, our study provides insights into the impacts on cross-country inequality. Finally, more broadly, our paper is related to the recent literature that studies the impact of deep trade agreements on various economic outcomes.⁶

Our paper relates to a strand of literature analyzing the determinants of cross-border patenting. Brunel and Zylkin (2022) find evidence that innovators patent in countries where they anticipate more trade. Similarly, using disaggregated French firm-level data, De Rassenfosse et al. (2022) find that patent protection at the product-destination level increases exports on that product and at that destination country. These results suggest that innovators may seek protection prior to enter a foreign market. Another motive for patenting in foreign markets has been provided by Gong et al. (2023), who find evidence of cross-border patenting as a quality signalling strategy for emerging economies. Finally, inventors may see protection in foreign markets to escape competition (Impullitti and Ates, 2021).

The paper is also related to recent work documenting the impact of trade liberalization on innovation. Using firm-level data on patent applications from PATSTAT, Coelli, Moxnes, and Ulltveit-Moe (2022) find that tariff cuts increase patenting at the country level. Cai, Li, and Santacreu (2022) study the impact of trade liberalization on innovation and diffusion in a multi-sector model of trade. Different from their approach, we investigate the effect of globalization on cross-border patenting, focusing both on the origin and destination of patents.

This paper contributes to the growing literature on patenting activity and diffusion. We build upon the work of Kortum and Lerner (1999), who investigate the factors driving the surge in US patenting during the 1980s and 1990s. Their decomposition of patent applications into source and destination country effects, as well as globalization and diffusion effects, provides a foundation for understanding the complex dynamics of patenting behavior. Furthermore, our research is closely tied to the multi-country models of in-

⁶See <https://datatopics.worldbank.org/dta/table.html>.

novation and diffusion developed by Eaton and Kortum (1996, 1999). In these models, the decision to patent in a foreign country is influenced by various factors, including the probability of imitation. The resulting expression for cross-border patenting depends on country characteristics and bilateral terms. Our paper takes a novel approach by exploring the specific determinants of cross-border patenting and their impact on income inequality.

The rest of the paper is organized as follows. Section 2 describes the INPACT-S dataset. In Section 3, we develop our theoretical model (in Subsection 3.1), and we translate it into an estimating equation (in Subsection 3.2). Section 4 presents our main estimation findings (in Subsection 4.1) and offers counterfactual analysis for the impact of patents on welfare and income inequality (in Subsection 4.2). Section 5 concludes with directions for future work. A Supplementary Appendix includes results and discussion from a series of robustness experiments and additional specifications.

2 The INPACT-S Database

Our new *International Patent and Citations across Sectors* (INPACT-S) database tracks international and domestic patent flows and citations across countries and industries over the period 1980-2019.⁷ In this section, we describe the methods that we used to construct INPACT-S (in Subsection 2.1); we highlight some of its key features by documenting several patterns of international patenting across industries and over time (in Subsection 2.2); and we show that INPACT-S is more comprehensive and has several key advantages over existing related datasets (in Subsection 2.3).

2.1 Constructing the INPACT-S Database

To construct INPACT-S, we rely primarily on the PATSTAT Global Autumn 2021. Using patent-level data from PATSTAT, we compute the number of patent applications from a

⁷We also construct a dataset of citations across country-sector pairs, which can be used to study knowledge flows across countries, as in Cai, Li, and Santacreu (2022). The details are relegated to an online appendix.

country of origin (i.e., the residence of the inventor or the owner of the technology) to an application authority at the International Patent Classification (IPC) level — 4-digit IPC codes — for the period 1980-2019. We account for both the applicant and the inventor, respectively.⁸ We then use concordance tables developed by Lybbert and Zolas (2022) to transform IPC codes into industry codes—ISIC Rev 3 2-digit. The result is a dataset that contains 91 patent authorities, 213 countries of origin, 40 years, and 31 ISIC Rev 3 2-digit codes. We describe in detail how we construct the dataset next.

We proceed in several steps. From the raw PATSTAT data, we use Structured Query Language (SQL) to pull `appln_id`, `person_id`, `earliest_pat_publn_id`, `appln_auth`, `person_ctype_code`, `appln_filing_year`, `publn_nr`, `publn_nr_original`, `publn_auth`, `publn_kind`, `ipc_class_symbol` from tables `tls201_appln` (table containing the bibliographical data elements of the application), `tls207_pers_appln` (table linking the applicants/inventors of the most recent publication to an application), `tls206_person` (table with identifying information on the applicants/inventors), `tls209_appln_ipc` (table containing the IPC classifications of an application), and `tls211_pat_publn` (table containing information about patent publications). These variables give us a raw dataset that reports, for each patent, the jurisdiction where the application was filed, the country of the applicant(s)/inventor(s), the year of application, and the full, disaggregated IPC class associated with each patent.

Importantly, we restrict our data to application type “A,” which in PATSTAT represents basic patents, and we do two separate pulls, one to get all persons who are inventors and another to get all persons/entities who are applicants. Moreover, rather than restricting the sample to the first patent in a family, we consider every patent from the same family. There is merit to analyzing only the first patent in the family, as one can get a better sense of breakthrough innovation, since all further patents in that family are a variation of that initial invention. However, our goal is to create a more comprehensive dataset that captures all innovation flows across the world because we seek to understand

⁸The inventor country of residence reflects the country of origin of the innovation, whereas the applicant country of residence reflects the ownership of the intangible. Not all applicants are necessarily inventors, as the inventor may simply develop a new technology while ownership resides with the firm that employs or funds her. For the same reason, being an inventor does not automatically make one an applicant. Importantly, in PATSTAT, firms can be applicants but cannot be inventors.

why patents are filed where they are. To this end, where the last patent in a family is filed holds just as much importance to us as where the first patent was filed.⁹

A few remarks are in order regarding how we treat patents filed by multinational companies. Patents are attributed to the country of the filing entity, which may not necessarily coincide with the location of the multinational's headquarters. For instance, if a subsidiary of a multinational company based in Ireland files a patent application in China, it is recorded as a patent flow from Ireland to China, despite the parent company being headquartered in another country. This approach is primarily dictated by the available data, as patent applications typically provide information on the filing entity and its location, but may not always identify the ultimate owner or the location of the headquarters. This can lead to potential drawbacks in accurately representing the true geographical distribution of patent ownership and innovation activities. However, for the purposes of our analysis, this may not be too problematic, as the primary focus is on the flow and interaction of patent activities between countries rather than pinpointing the exact origin of multinational innovation.

We make several adjustments to the raw data, which we explain next. First, we aggregate the IPC classifications to the 4-digit level. Second, in many instances, one application may feature multiple applicants/inventors from different countries. Similarly, for a majority of applications, a single patent belongs to multiple IPC technology classifications. To avoid counting the same applications multiple times for different origins/classifications, we employ a fractional counting method for both technology class and origin country. For example, if an application has four inventors, one from the US and three from Canada, then this will be counted as 0.25 patents from the US and 0.75 from Canada, as opposed to four different applications. To ensure consistency, we implement built-in checks and crosscheck with the OECD, which also relies on a fractional method.

We use the same idea to avoid counting one patent that falls into multiple IPC classification as multiple different applications. If, as in our example above, the IPC classifications of the patent are G06F 1/04, G06F 1/16, and G08B 1/02, then 0.67 of the

⁹The EPO defines a patent family as “A patent family is a collection of patent applications covering the same or similar technical content.”

application is assigned to G06F and 0.33 is assigned to G08B. This means that in the case of the four inventors described above, the Canadian inventors receive credit for 0.75 of the patent, and 0.67 of that is assigned to the G06F classification. This results in a total of 0.5 patents assigned to the Canadian G06F class.

Third, in several cases, applications are filed to regional patent authorities covering two or more countries rather than a single country. This is a decision made at the individual level. In some cases, applicants may opt for the cheaper upfront cost of applying to just one or two European countries, and others may decide to go the more expensive route and apply to the European Patent Office (EPO) as a whole, which is cheaper than applying to many countries individually. As recognized by WIPO, the major regional authorities are African Regional Intellectual Property Organization (ARIPO), EPO, Eurasian Patent Organization (EAPO), Gulf Cooperation Council (GCC) Patent Office, and Organisation Africaine de la Propriété Intellectuelle (OAPI).¹⁰ Under these jurisdictions, applicants can send one application to these authorities for a singular granting process and receive the possibility of protection in all fully ascended member states.

We attempt to take the regional patent authority application totals and disperse them in favor of individual member country applications. To this end, we make the reasonable assumption that not all member states of an authority are attracting patent applications equally. For example, it is likely that far more applications filed with the EPO are intended to be used to protect IP in a large, traditionally innovative country, such as Germany, than in a smaller member, such as Slovenia or Liechtenstein. Therefore, when measuring the main destinations of cross-border patents, equating all patents to the EPO to count as one for each and every member state would paint a skewed image of technology transfer. This approach could make small countries that are part of a large regional authority seem like more of a technology destination than they are in reality.

To address this issue, we employ a weighted-dispersion method in which we allocate patent applications, from an origin to a regional authority, across the individual member states of that regional authority. We base this dispersion probability on the share of direct

¹⁰<https://www.wipo.int/patents/en/topics/worksharing/regional-patentoffices.html>

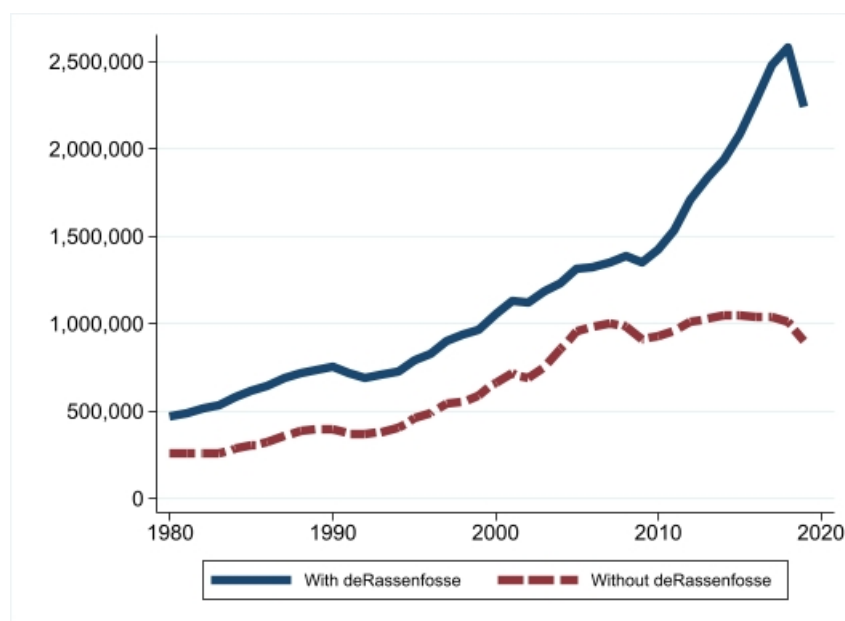
patent applications from each origin country to each individual member state in that same year and technology class. To visualize this point, imagine a hypothetical regional patent authority, UKESPDEU, which consists of only the United Kingdom, Spain, and Germany. Suppose that applicants from Australia filed 100 patents in the textiles industry with UKESPDEU in 2022. Suppose that, also in 2022, Australian applicants filed 25 textile patents directly in Germany, 10 textile patents directly in Spain, and 5 textile patents directly in the United Kingdom. Out of these 40 directly filed patents, Germany received 62.5%, Spain received 25%, and the United Kingdom received 12.5%. These shares serve as the probabilities of the intended final destination of patents filed to the regional authority. We use these probabilities as our weights to disperse out the patents filed to UKESPDEU. Following this method, dispersing the 100 Australian textile patents filed to UKESPDEU and adding them to the direct totals would result in 87.5 patents to Germany, 35 patents to Spain, and 17.5 patents to the United Kingdom.

Fourth, we address a commonly discussed problem of PATSTAT database. Since PATSTAT is maintained by the EPO, they are unable to edit the data voluntarily provided to them by other authorities that are sometimes lacking in detail. This results in a prevalence of missing data in a number of categories, including in the country of the applications' applicant(s)/inventor(s), as documented by De Rassenfosse, Kozak, and Seliger (2021). We follow two steps for imputing blank origin countries. In the first step, we use the SQL code provided by De Rassenfosse, Kozak, and Seliger (2021) to impute missing values in the raw PATSTAT data. Before imputation, there are over 26 million applicants with a known origin from 1980-2019 and nearly 24 million inventors in our dataset; after applying their method, we have over 46 million applicants and 44 million inventors.

Figure 1 showcases the differences in known origins before and after imputation for each year in our sample. They use familial linkages between worldwide applications to impute the origin that is missing, based on data found in related patents filed elsewhere. Patents for the same technology are often filed in more than one jurisdiction (or even in the same jurisdiction for a slightly different but related technology). One authority

may report incomplete information on the origin of a patent, but another authority may report more complete information for the same (or similar) technology in the same family. PATSTAT provides data that can be used to link priority filings with subsequent filings across the globe, making it possible to take information from related patent applications to impute the missing information, which is precisely what their provided code does. In brief, their method can be summarized as the following: If the information is not available on the patent application, search for the information from direct equivalent patents in the same family. If the information cannot be found on those direct equivalents, search for the information in subsequent filings in the same patent family. This continues on until all possibilities are exhausted.

Figure 1: Imputing missing values with De Rassenfosse, Kozak, and Seliger (2021)



Note: This figure shows, for each year, the difference between the applicants we have with known origins before and after using the De Rassenfosse, Kozak, and Seliger (2021) imputation method.

The De Rassenfosse, Kozak, and Seliger (2021) method, although impressively comprehensive, is unable to account for all missing origins. In the second step, instead of simply dropping the remaining blank origin data, we use the aggregate bilateral data from WIPO to disperse the remaining “origin missing” applications. At the current stage, after applying all the edits stated above, our dataset contains authority, IPC 4-digit class,

year, and origin. However, for every authority, in each year, in each ISIC industry there exists a blank country of origin with some patents attributed to it. Our goal is to assign all these remaining patents to origin countries rather than simply lose that data.

One possibility would be to follow a method similar to the one described above for the dispersion of regional authorities' applications. That is, dispersing applications based on shares of the applications, which are already assigned. However, this method might be a biased way of dispersing the "missing origin" applications. Some origins have more robust patent families for the De Rassenfosse, Kozak, and Seliger (2021) method to pull from. In addition, some authorities report better data than others, and these authorities receive applications from different origins at different rates. For example, Japan reports Japanese origins very well but is less reliable on reporting cross-border patents. Additionally, in recent years, China rarely reports origin countries at all to the EPO. As a result, using shares derived from our existing dataset would be reinforcing established biases in the data.

To account for this problem, we instead use the WIPO aggregate bilateral data as a proxy. We take the authorities from WIPO and compute the share of total patents for each authority that originate from each origin country for a given year. We then, as with the regional authorities described above, apply those probabilities to the "missing origin" data, and distribute them based on these WIPO weights. A key assumption with this approach is that the probabilities are assumed to be constant across all technology classes for each origin/authority/year relationship. Roughly 9% of our observations by applicant are dispersed with this method and 11% of our patents by inventor.

Finally, the 4-digit IPC technology classes are converted into ISIC rev. 3 2-digit industries using a crosswalk that can be found in Goldschlag, Lybbert, and Zolas (2016).¹¹ Our patent numbers for each technology class are multiplied by the probability weights provided and then summed by industries to give us a bilateral patenting dataset by country and industry rather than technology class.

¹¹<https://sites.google.com/site/nikolaszolas/PatentCrosswalk>.

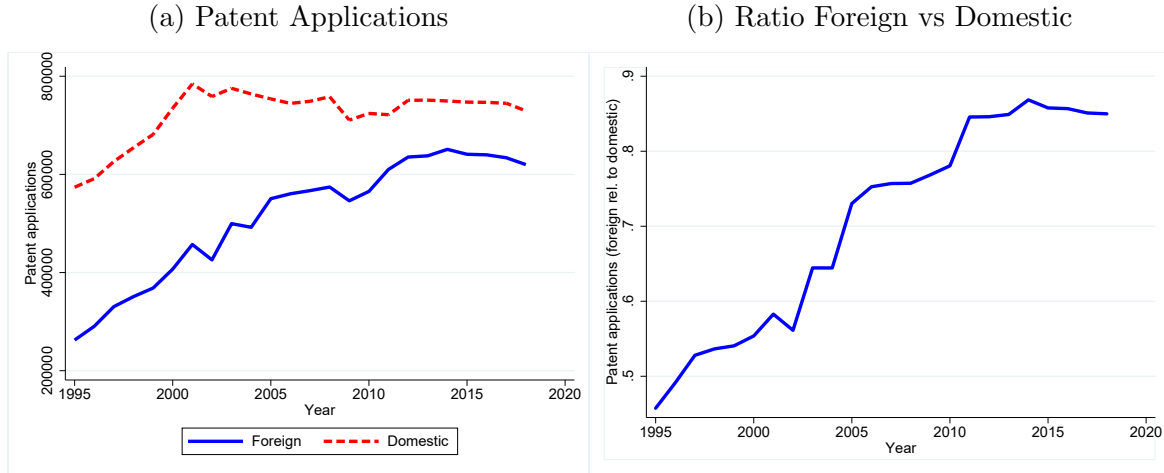
2.2 Salient Features of Patent Flows

INPACT-S uncovers several interesting features of patent flows across countries, industries, and over time. Among other facts, we find that international patent applications have grown faster than domestic patent applications, especially from developed to developing countries. We highlight the rise of Asia as both an origin and a destination of patent applications over the past decades. Asian countries increasingly becoming destinations for patent applications suggests a flow of technology from traditionally innovative countries. This exchange has the potential to drive development in Asia, as the countries gain access to advanced knowledge, methodologies, and technologies from developed countries. Indeed, we also observe that more Asian countries are becoming origins of patents, implying they are becoming more innovative themselves.

Foreign vs Domestic Patent Applications. Figures 2 and 3 illustrate the evolution of domestic and foreign patent applications over time, with Figure 2 excluding China and Figure 3 including it. Both figures show that foreign patent applications have grown faster than domestic applications. Specifically, between 1995 and 2018, foreign patent applications (excluding those from China) grew by 136%, significantly outpacing the 27% growth in domestic applications. The right panel of Figure 2 shows the ratio of foreign to domestic patent applications, which has steadily increased from 0.5 in 1995 to nearly 0.9 in 2018, indicating that innovators are increasingly seeking patent protection in foreign markets.

Figure 2 reveals three distinct periods in the evolution of cross-border patenting versus domestic patenting. Before 2000, foreign and domestic patent applications grew at a similar pace, with a relatively stable ratio of foreign to domestic applications around 0.5 to 0.6, indicating a balanced distribution of patenting activities. From 2000 to 2010, foreign patent applications grew at a faster rate than domestic ones, leading to a narrowing of the gap between the two, even though domestic applications remained larger in absolute numbers. This faster growth of foreign applications is reflected in the steady increase in the ratio of foreign to domestic applications during this period, signaling a

Figure 2: Patent Applications: Domestic vs Foreign (excluding China)

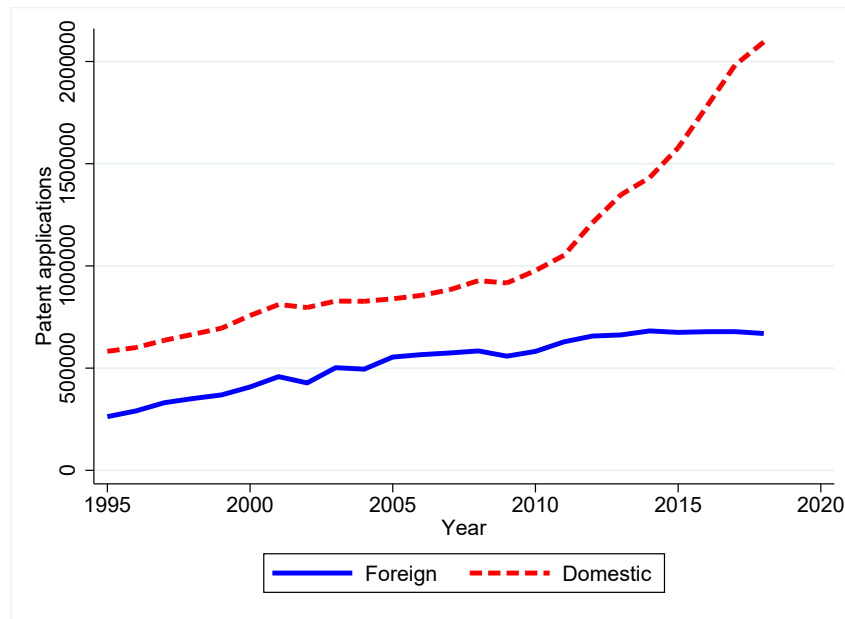


shift towards internationalization in patenting activities. After 2010, both foreign and domestic applications continued to grow at a more similar rate compared to the previous decade, leading to a stabilization in the ratio of foreign to domestic applications around 0.8 to 0.9, suggesting a more balanced growth in recent years, albeit with a higher level of internationalization compared to the pre-2000 era.

This faster growth of foreign patent applications can be attributed to several factors, such as the harmonization of patent laws through the Patent Cooperation Treaty (PCT), globalization of policy, and the improvement of IP protection as part of trade agreements. The PCT has streamlined the process of filing international patent applications, making it easier for innovators to seek protection in multiple countries. Moreover, globalization has led to increased international trade and foreign direct investment, which has incentivized companies to protect their IP in foreign markets. Lastly, the inclusion of IPR chapters in trade agreements has strengthened patent protection in participating countries, encouraging more cross-border patent filings.

When China is included in the analysis, the picture changes slightly due to China's dramatic increase in domestic patent applications. China's explosion in domestic patenting is unprecedented, with the number of domestic applications increasing by a factor of 162 between 1995 and 2018. This remarkable growth may be attributed to China's generous patent subsidy programs, which are set to be phased out by 2025, as announced by the China National Intellectual Property Administration (CNIPA) on January 27, 2021.

Figure 3: Patent Applications: Domestic vs Foreign (including China)



The origins of innovation. Figure 4 shows the worldwide distribution of patent applications per million people filed by (i) domestic inventors inside the country—domestic applications—in the upper panel, and (ii) domestic inventors to the world—cross-border applications—in the bottom panel, throughout the decade of the 2010s.¹²

The figure shows that innovation is concentrated in a few countries, mainly in Europe, the United States, and Eastern Asia. While Europe and North America have traditionally been innovation hubs, our data show the rise of Eastern Asian countries as new innovators. In terms of domestic patent applications, China stands out as the main innovator. Indeed, 37% of all patent applications being filed around the world in the 2010s can be attributed to Chinese domestic applications. The other leaders of total domestic applications were Japan, the United States, South Korea, and Germany in that order.

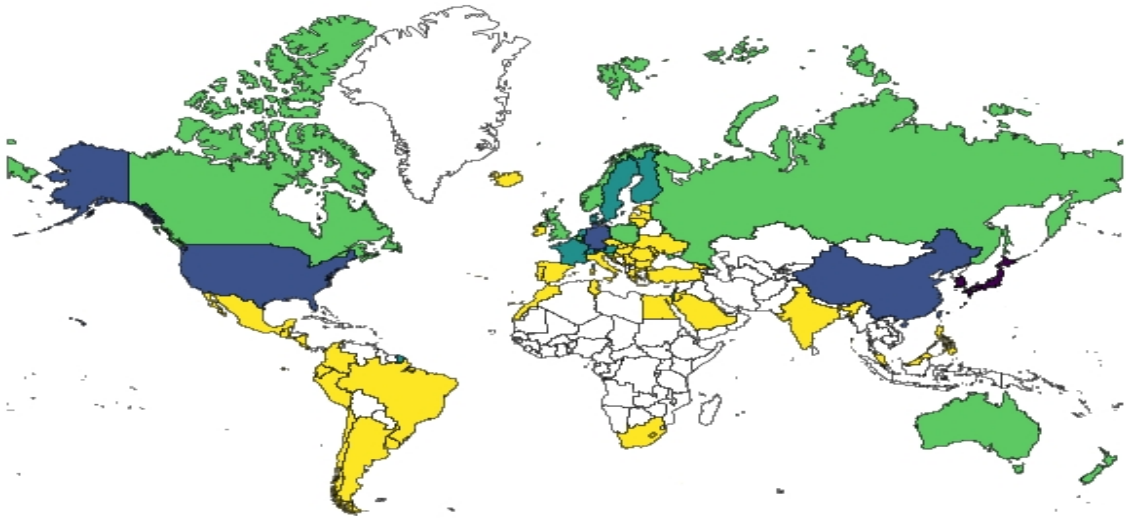
The rise of Eastern Asian countries on the world innovation stage centers around four countries: Japan, South Korea, China, and Taiwan.¹³ Japan and South Korea are more traditionally innovative countries, with their technology sectors dating back decades, while China and Taiwan have become new powerhouses of innovation, with a growth in the number of domestic patent applications between 1995 and 2018 by a factor of 13 in

¹²Population is calculated by taking the average across the decade.

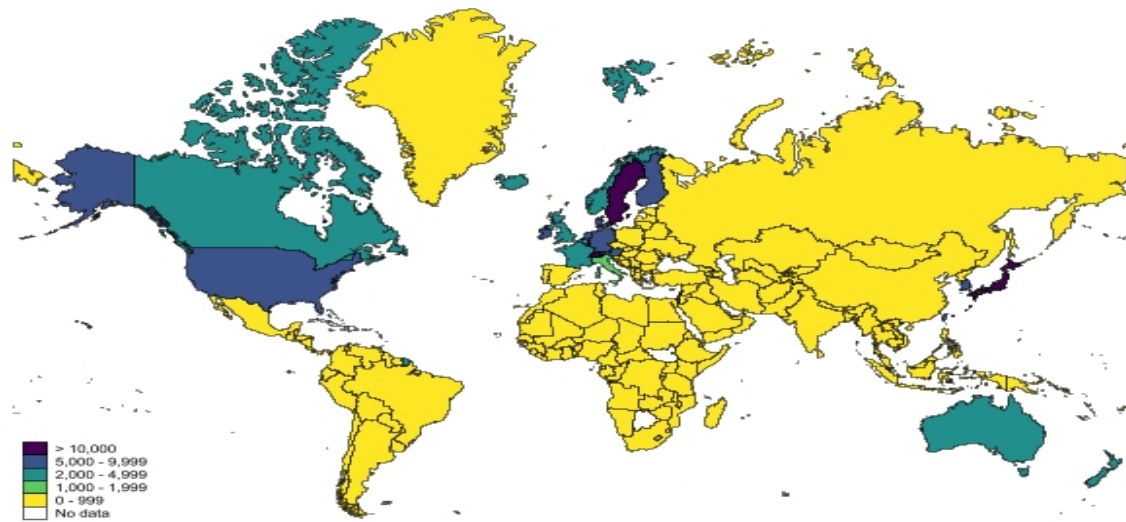
¹³Eastern Asia also includes Hong Kong and Mongolia but their overall values are small and inconsequential so we focus on the four mentioned.

Figure 4: Origins of Innovation

(a) Domestic patent applications



(b) Cross-border patent applications



Note: The upper panel (a) shows the number of domestic patent applications per million people in the 2010s; the bottom panel (b) shows cross-border patent applications per million people in the 2010s. Blank countries do not have data available as authorities.

Taiwan and by a factor of 162 in China. China’s explosion in terms of domestic patenting is unprecedented. In fact, there is reason to believe that this remarkable growth can be attributed to China’s generous patent subsidy programs. However, on January 27, 2021, the China National Intellectual Property Administration (CNIPA) announced that these subsidies are to be phased out by 2025.

Aside from the domestic market, these 4 countries have also become important sources of cross-border patent applications. Japan, likely due to the age of its technology sector, dominates the other Eastern Asian countries in the number of patent applications filed abroad. However, South Korea has become more prominent in the international patent market beginning in the 90s, followed by Taiwan and China in the 2000s. Interestingly, China’s unprecedented domestic patent growth has not been replicated on the international level in terms of the total number of cross-border patent applications filed, but the growth rate has. Though their cross-border patent applications are dwarfed by their domestic applications, China has still seen an increase by a factor of 230 in terms of cross-border applications filed from 1995 to 2018. These trends indicate an increase in these countries’ presence in terms of innovative activity.

If we isolate the analysis to cross-border patent applications, applications filed by each origin country to the world excluding domestic applications, the picture looks slightly different. The main discrepancy lies in China, where Chinese innovators seek protection mainly domestically. Indeed, out of all patent applications to the world during the 2010s, only 1.5% are accounted for by Chinese cross-border patents. Again, this discrepancy is an indication of the market intervention introduced by the Chinese government in the late 2000s that sought to incentivize patent applications through a subsidy.¹⁴ During the decade, the main innovators seeking protection abroad are Japan, the United States, Germany, and South Korea. From the 1990s to the 2010s, we find that Japan, South Korea, and Taiwan are the countries that have experienced the largest increase in the number of cross-border patent applications per million residents filed.¹⁵

¹⁴<https://www.stlouisfed.org/on-the-economy/2018/february/china-overtaken-us-terms-innovation>.

¹⁵This is excluding countries that are commonly labeled as “Tax Havens”, which typically saw incredible patent growth over this period.

To better illustrate the emergence of new regions as origins of patent applications, we partition the countries in our dataset into regions.¹⁶ Figure 5 shows the evolution of patenting across the different regions. In the upper panel, we show the total number of cross-border patents filed by the countries in each world region, whereas in the bottom panel we show the same but for the countries that make up Eastern Asia.¹⁷

What stands out in the upper panel is Eastern Asia catching up to North America in terms of foreign applications filed in the mid-2000s and maintaining the lead since. Also notable is the speed at which Eastern Asia caught up to North America, closing the gap with the United States very quickly after the turn of the century. No other region comes close to matching Eastern Asia's growth over this time frame. From the bottom panel, we can see that this growth was largely due to Japan and, to a lesser extent, South Korea. However, while Japan, South Korea and Taiwan have plateaued in recent years, China has begun their own rapid growth as inventors of cross-border patents.

If we focus on patent applications to other countries within the region, we observe a strong bias of Eastern Asian countries to file cross-border patents that remain within the region (Figure 6). Beginning in 1990s, Eastern Asian countries began rapidly filing patents to other countries in the region, and after 2000, around the time of China's ascension to the WTO, this grew even faster while most other regions either stayed steady or increased just moderately over this span. This is consistent with an overall trend towards Eastern Asia in the global patent market.

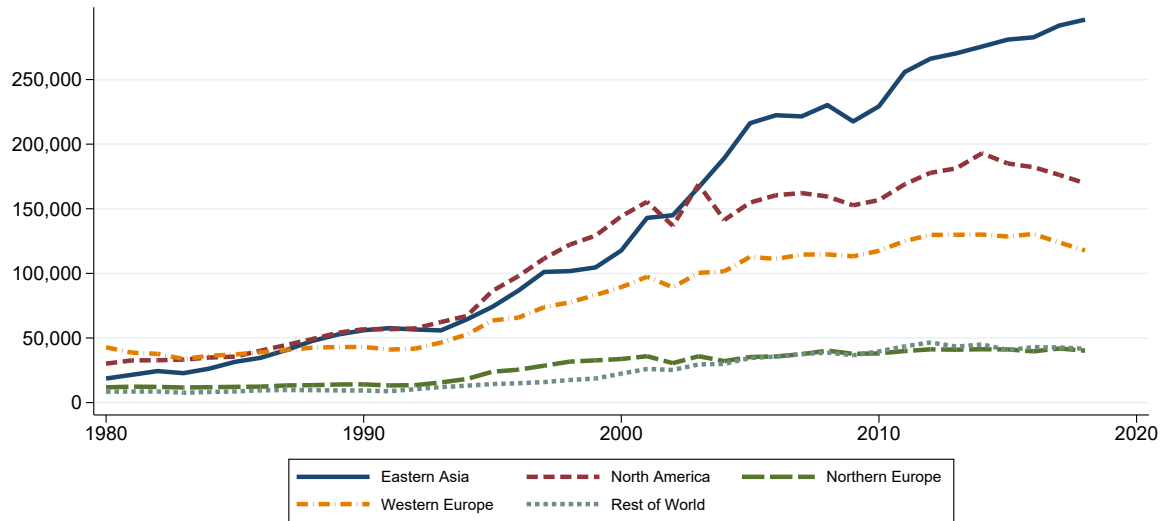
The Destinations of Innovation. So far, we have documented the rise of Asia as an innovation hub. In this section, we investigate the following question: Where are innovators seeking protection for their ideas? Figure 7 shows that Eastern Asia has risen as a destination of cross-border patent applications in addition to being an innovator. This suggests that the region may be seen as a competitor destination to traditionally

¹⁶We use regions as defined by the UN <https://unstats.un.org/unsd/methodology/m49/>: Australia and New Zealand, Central Asia, Eastern Asia, Eastern Europe, Latin America, Melanesia, Micronesia, Northern Africa, Northern America, Northern Europe, Polynesia, South-eastern Asia, Southern Asia, Southern Europe, Sub-Saharan Africa, Western Asia, Western Europe.

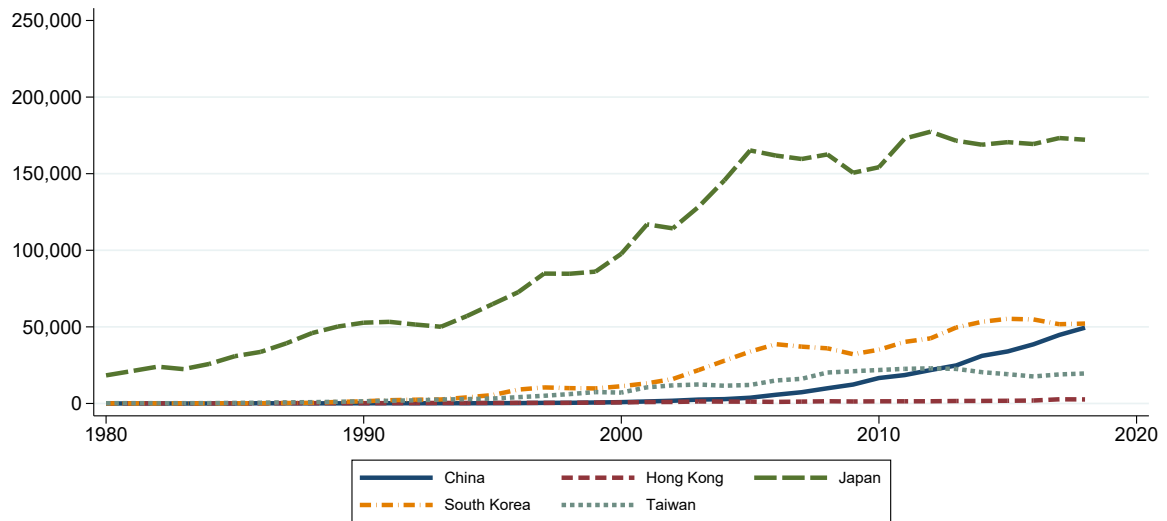
¹⁷Cross-border patents are determined at the jurisdiction level rather than the regional level. A patent from South Korea to Japan occurs in the same region but is a cross-border application.

Figure 5: Patent Evolution by Region of Origin

(a) World Regions

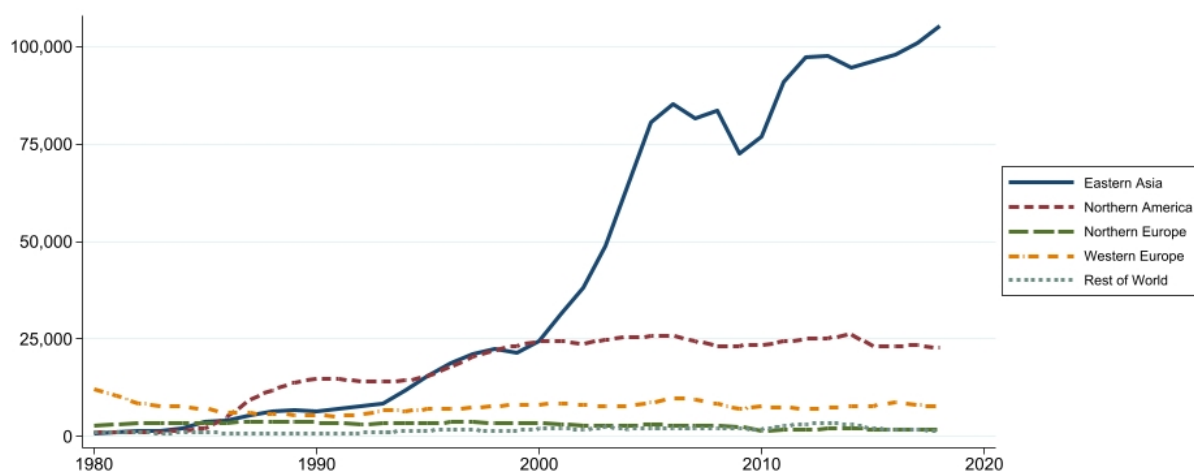


(b) Eastern Asia



Note: The upper panel (a) shows cross-border patent applications filed by the countries of different regions of the world; the bottom panel (b) plots patent applications filed by each country in Eastern Asia.

Figure 6: Regional Bias in Patenting Applications



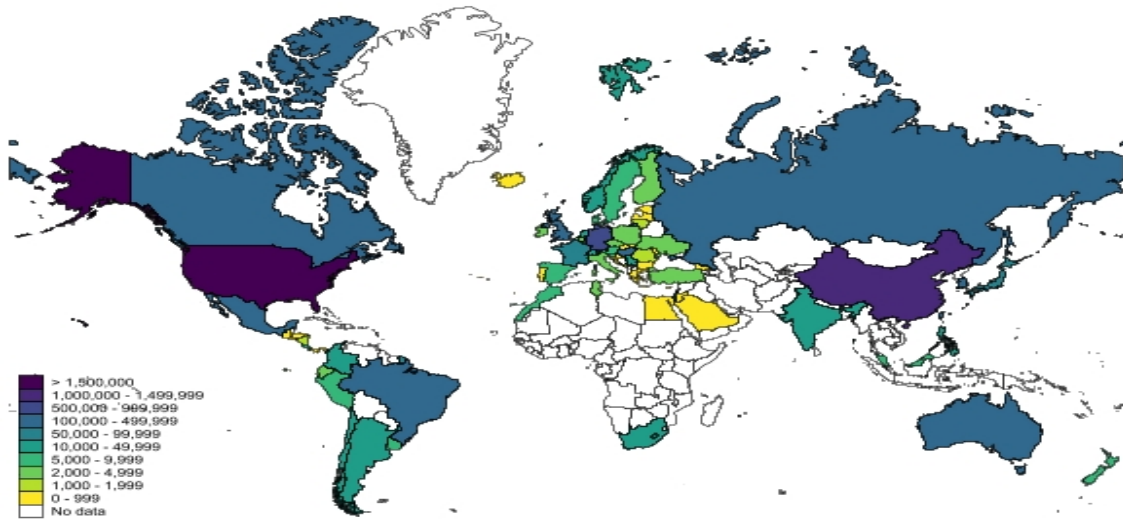
Note: This figure shows the number of cross-border patents filed by countries of a region which were filed elsewhere in that same region. The Rest of the World is an aggregate where we first compute this intra-region number for each region individually and aggregate them together.

innovative countries, such as the US. By the 2010s, the US and China have dominated as destinations where inventors seek protection of their IP, being the only countries to attract more than a million cross-border patent applications in the decade.

Additionally, South Korea attracted the 4th most cross-border patents, while Taiwan attracted the 7th most. There are two possible reasons for this: either these countries are becoming more innovative and competing with western innovation such that innovators want to ensure their technology is protected from imitation here, or typically innovative countries are doing more business in these countries, leading to an increased need for ensuring business assets are protected.

International Patenting Across Industries. Next, we leverage the industry dimension of the data and ask the following question: In what industries are innovators seeking international protection? Taking the United States as the world innovation leader, we find that patent applications from the United States to the world are concentrated in a few industries: Chemicals, Computers and electronics, and Medical and optical equipment. These are also R&D-intensive industries in that they account for most of the R&D spending and number of patents being created around the world. Second, we find that nine

Figure 7: Main Destinations of Cross-border patents in the 2010s



Note: This figure shows the number of cross-border patent applications received in the 2010s. Blank countries do not have data available as authorities.

countries account for more than 80% of cross-border patent applications filed by United States applicants to the world: China, Canada, Great Britain, Australia, Germany, South Korea, Taiwan, Brazil, and Mexico. In Table 1, we report the share of patent applications from the US to each of these countries across five of the most R&D-intensive industries.

The table shows that about one-third of the patents filed by the US in Mexico, one-fourth of the patents filed in Canada and South Korea, and one-fifth of those filed in China, UK, and Taiwan are in the chemical industry. However, in the case of Germany, US inventors seek protection mainly in the medical and optical equipment industry. Also notable is Taiwan, where 19% of US patents in Taiwan after the turn of the century were in the radio, television, and communication equipment industry, far higher than shares to other countries. This is notable because of Taiwan's importance in the semiconductors industry and the fact that this industry comprised just 7% of US patents to the rest of the world over this same period. Additionally, 14% of patents filed in Germany were in machinery, which is more than double its share of US patents filed in the rest of the world. Differences in patent applications across industries and countries could be explained by supply chain linkages requiring countries to seek protection in a particular industry, depending on the particular position in the supply chain.

Table 1: Industries of Patents filed by the US, Post 2000

Destination	Chemical Mfg	Computing	Machinery n.e.c.	Medical /Optical Equip	Radio/TV/ Comms Equip
Australia	27%	12%	5%	14%	3%
Brazil	30%	9%	7%	11%	3%
Canada	25%	10%	7%	13%	3%
China	16%	13%	9%	15%	10%
Germany	9%	13%	14%	18%	7%
UK	16%	21%	5%	18%	6%
Korea	23%	17%	4%	15%	11%
Mexico	32%	7%	6%	9%	3%
Taiwan	19%	17%	3%	15%	19%
ROW	17%	21%	6%	16%	7%

Notes: The table reports the share of patent applications from the US to each of the countries across five of the most R&D-intensive industries. R&D intensity is computed as the proportion of patents generated by each industry in relation to the overall number of patents across all industries.

The empirical findings suggest that innovators from developed countries are increasingly seeking patent protection in Asia primarily to facilitate market entry and operations. The data reveals a significant share of U.S. patents filed in countries like China, South Korea, and Taiwan are in high-tech sectors such as chemicals, computers, electronics, and communication equipment, aligning with the growing technological capabilities and market opportunities in these Asian economies. This concentration of cross-border patents in industries closely tied to the strengths and demands of Asian markets points to a strategic, market-seeking approach to patenting by innovators from rich countries. In other words, innovators may strategically be seeking patent protection in Asia to capitalize on market opportunities and align with the region’s technological strengths.

2.3 Comparison with Alternative Datasets

Our novel INPACT-S dataset complements and improves on existing patent data publicly available from the United States Patent and Trademark Office (USPTO), the Organisation for Economic Co-operation and Development (OECD), and the World Intellectual Property Organization (WIPO), along several dimensions.

While the USPTO only accounts for patents filed in the United States, the OECD database is slightly more comprehensive, including patents that have been filed in the United States (USPTO), in the European Union (EPO), and under the Patent Cooperation Treaty (PCT). In contrast, our dataset covers 91 patent offices around the world. This extension is important in capturing the innovation trends observed in the past four decades, in addition to the rise of new players in the knowledge sector.

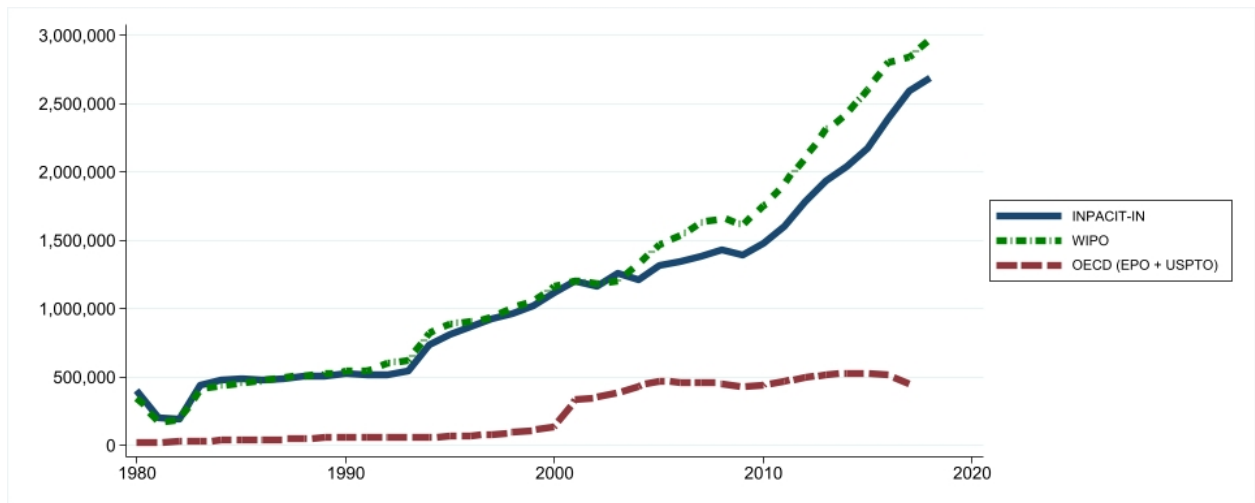
The WIPO dataset is closer to ours, as it includes patent applications filed in all patent offices for which data are available, but it does not report the data at the industry level and differs in the way it imputes some data points, as we elaborate on later. Hence, our dataset is more comprehensive than other existing publicly available datasets on international patenting flows. Beyond just these improvements, we provide data on citations across country-sector pairs, which allows us to compute a measure of quality-adjusted patent applications, as explained in the Appendix, used in the robustness tests.

Figure 8 shows the comparison of our dataset with the OECD and WIPO. For this comparison, we use the patent applications by applicant counts.¹⁸ One important difference between the WIPO and our dataset is that the WIPO dataset does not have an industry dimension. Therefore, for comparison we must aggregate across our industries by bilateral relationships and year in our final dataset. We also aggregate OECD patents filed to USPTO and EPO.

Aside from a slight divergence in the early 2000s, our method matches the aggregate trends in the WIPO data extremely closely. However, there are a few important differences between the methods used to derive our data and the WIPO data. First, as described above, we find it unrealistic to assume each country in a regional authority is equally attracting patents to that authority. WIPO instead chooses to count the patents for these authorities by assigning one patent to each jurisdiction in the region. Furthermore, rather than fractionally dispersing out the patent equally amongst the applicant(s)/inventor(s), WIPO chooses to assign the patent to the country of the first applicant, under-counting the number of patent applications originating in some jurisdic-

¹⁸By definition, fractional counting creates identical totals in aggregate whether summed by applicant or inventor despite the fact individual bilateral relationships may differ.

Figure 8: Comparisons with similar datasets



Note: The green line represents the aggregate WIPO world patent totals by year while the blue line represents INPACT-S totals after using the methods described above. The red line represents OECD, EPO, and USPTO patents. OECD has a group of applications filed under the PCT, but since they do not provide indicators as to where those applications are going we leave them out. Including those just increases their total slightly each year.

tions. Since we are focused on understanding where innovators from different countries seek protection for their inventions, we see value in recording the origin of every applicant/inventor rather than just one.¹⁹

The discrepancies between our dataset and the OECD dataset reflect the additional patent offices we capture with ours, while the OECD restricts the sample to patent applications filed to just the EPO and USPTO patent offices.²⁰ Note that these differences are increasing over time, as new countries begin attracting more patent applications and are becoming new innovation powerhouses.

Having identified some of the main differences between our data and the OECD and WIPO datasets, we want to make sure that the choices and assumptions made in the construction of our dataset are reasonable and do not yield aggregate numbers that differ significantly from those reported by these more established datasets.

We begin by computing the correlation between INPACT-S and publicly available OECD and WIPO datasets. For comparison to the OECD, we take the raw PATSTAT

¹⁹<https://www.wipo.int/ipstats/en/help/>

²⁰The OECD also has PCT patents, but those provide no value in discerning bilateral patent trends.

data and employ our fractional method to patent applications filed to the EPO and the USPTO, the only jurisdictions available in the OECD dataset. Moreover, we do not impute any missing country codes. Here, we are only attempting to measure the accuracy of our fractional counting of the raw patent data.

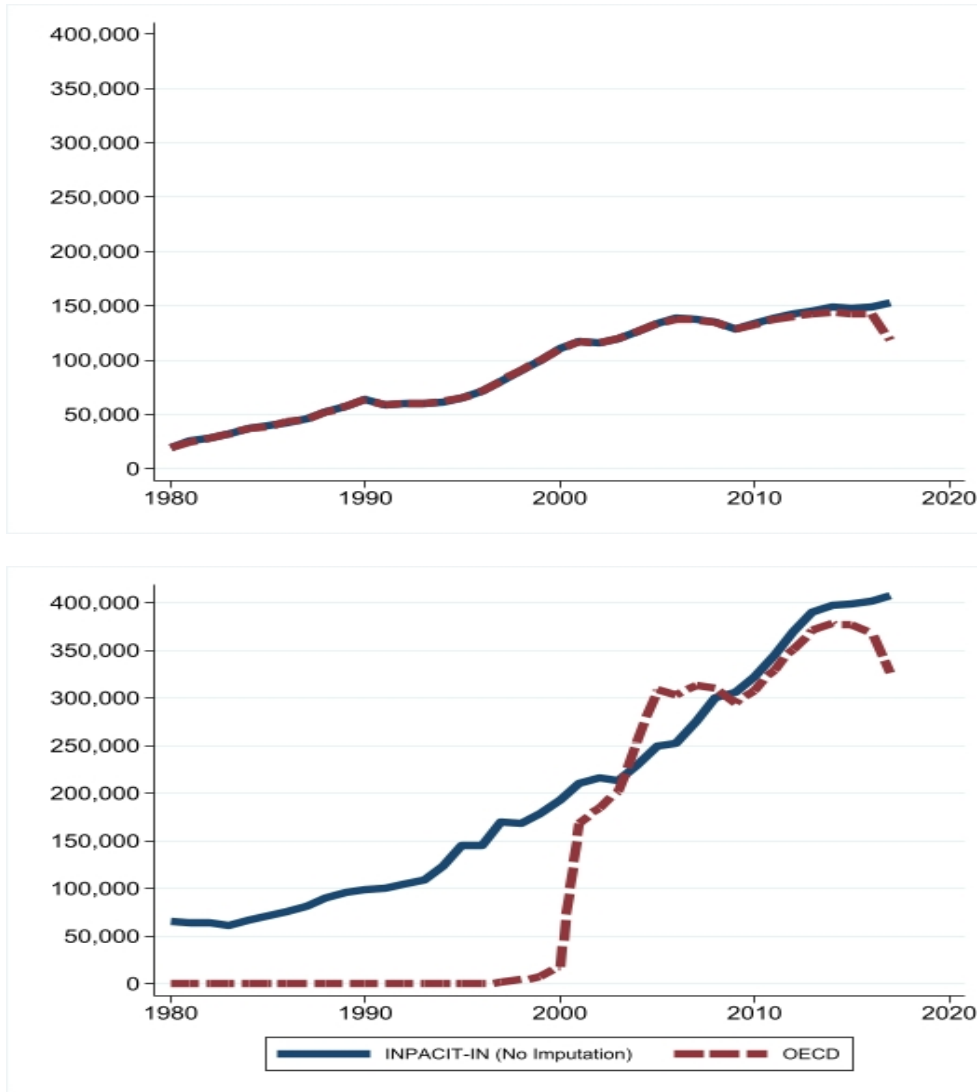
For the full sample period, 1980-2019, our data are consistent with the OECD data, with a correlation of around 90% for international patenting by both applicants and inventors. When we restrict the sample to just 2010-2018 the correlation is nearly 100% for both. The reason is twofold: (i) Patent data have a lag in reporting and are only reliable after a few years, so dropping 2019 helps clean some of the noise, and (ii) the data provided by the OECD that cover patents filed to the USPTO are exceptionally poor prior to 2010.

Figure 9 shows the evolution of patent applications to the EPO and USPTO over the period of analysis using our data and those provided by the OECD dataset. In the upper panel, we observe that, overall, our dataset perfectly tracks world applications to the EPO from 1980 until very recently, when the OECD reports a sharp decline not found in our data. In contrast, our dataset captures a steady rise in patent applications to the EPO even in the most recent years. In the bottom panel, we restrict to patent applications to the USPTO as reported by the OECD dataset. The data provided by the OECD are poor prior to 2000 and follow an unrealistic growth trend afterward, while our dataset provides a more realistic growth pattern.

3 Cross-border Patenting and Globalization: Theory and Empirics

Motivated by the patterns that we have uncovered and described based on the INPACT-S database, in this section we ask the following questions: “What drives cross-border patenting?” and “What are the implications of the changing cross-border patenting patterns for global inequality?” To answer these questions, in Subsection 3.1, we develop a model of cross-border patenting, globalization, and development, which guides our empir-

Figure 9: INPACT-S (without imputation) vs OECD



Note: The upper panel shows patents filed to the EPO from the world according to our data (blue line) and the OECD data (red line); the bottom panel plots patents filed to the USPTO filed by the world according to our data (blue line) and the OECD data (red line).

ical analysis. An important byproduct of our theory is the derivation of a gravity model for cross-border patent flows, which enables us to obtain our own partial estimates of the effects of globalization and policy with the INPACT-S database. In Subsection 3.2, we capitalize on the latest developments in the trade, migration, and FDI gravity literature to translate our theoretical model into an estimating gravity equation for cross-border patents.

3.1 A Theory of Cross-border Patenting and Globalization

We develop a multi-country model of innovation and technology diffusion to analyze the patenting decisions of innovators that want to maximize their returns to R&D investment while minimizing the risk of imitation. There are M countries, indexed by i and n . Time is discrete and indexed by $t \in \{0, \infty\}$. Countries exchange trade and ideas. The trade model consists of an Armington framework where each country produces differentiated intermediate goods that are traded internationally, subject to trade costs. Technology is determined by innovation and technology diffusion and subject to imitation and patenting decisions.

Innovators invest in R&D to create new ideas, which serve as blueprints for differentiated goods. These ideas can diffuse and be used to produce intermediate goods, generating payments for the innovators. Diffusion increases the likelihood of ideas being used in production, thereby increasing returns to R&D. However, diffused ideas face the risk of imitation. To mitigate this, innovators file patents in every jurisdiction where their ideas have spread.²¹ Unpatented ideas are imitated with certainty, while only patented ideas generate payments for innovators, as they are imitated with a lower but positive probability. The level of technology in each country is determined by the number of ideas that are used for production, as suggested by Romer (2005) and Grossman and Lai (2004).

3.1.1 International Trade Model: Static Equilibrium

Given the level of technology and trade costs at time t , an Armington trade model determines the static equilibrium.

Final Production. A final producer in each country n uses intermediate goods, both domestic and foreign, to produce a final good, Y_{nt} , with a CES technology

²¹This resembles a world in which innovators license their technology to a foreign firm and file a patent application prior to licensing.

$$Y_{nt} = \sum_{i=1}^M \left(\int_{j=1}^{T_{it}} X_{ni,t}^{\frac{\sigma-1}{\sigma}}(j) dj \right)^{\frac{\sigma}{\sigma-1}}, \quad (1)$$

where T_{it} is the number of products being produced in country i , $X_{ni,t}(j)$ is the amount of good j from country i demanded by country n , and σ is the elasticity of substitution across varieties. The demand for intermediate goods from country i by final producers in country n is given by

$$X_{ni,t}(j) = \left(\frac{p_{ni,t}(j)}{P_{nt}} \right)^{-\sigma} Y_{nt}, \quad (2)$$

where $P_{ni,t}(j)$ is the price charged by each intermediate producer j in country i selling to country n and P_{nt} is the price level, given by

$$P_{nt} = \sum_{i=1}^M \left(\int_{j=1}^{T_{it}} p_{ni,t}(j)^{1-\sigma} dj \right)^{\frac{1}{1-\sigma}}.$$

Intermediate Production. Each intermediate good j in country n is produced by a monopolistic competitive firm according to

$$y_{nt}(j) = \Omega_{nt} l_{nt}(j), \quad (3)$$

where $y_{nt}(j)$ is the amount of intermediate good j produced in country n , Ω_{nt} represents fundamental productivity in country n , and $l_{nt}(j)$ is the amount of labor used to produce intermediate good j . The firms choose labor and prices taking as given the demand by final producers. Prices are set as a constant markup of the cost, which is given by wages. The mark up is given by $\bar{m} = \frac{\sigma}{\sigma-1}$ and prices are given by

$$p_{ni,t}(j) = \bar{m} W_{it} d_{ni}, \quad (4)$$

where W_{it} is the wage, and d_{ni} is an iceberg transport cost from selling goods from country i to country n . In a symmetric equilibrium, the resulting price of the final good producer is given by

$$P_{nt} = \sum_{i=1}^M \left(\Omega_i^{\sigma-1} T_{it} p_{ni,t}^{1-\sigma} \right)^{\frac{1}{1-\sigma}}. \quad (5)$$

Trade Shares. Given technology, T_{nt} , and trade costs, d_{in} , the share of goods that are imported by country i from country n , $\pi_{in,t}$, is given by

$$\pi_{in,t} = \Omega_{nt}^{\sigma-1} T_{nt} \frac{(\bar{m} W_{nt} d_{in})^{1-\sigma}}{P_{it}^{1-\sigma}}. \quad (6)$$

The previous equation is a version of the standard gravity model of trade.

3.1.2 Growth Model: Innovation, Diffusion, and Cross-border Patenting

Technology evolves endogenously through two processes: innovation and technology diffusion. Innovators invest resources to create an idea. Ideas diffuse across countries through an exogenous process. Diffused ideas can be used to produce intermediate goods. As technologies are non-rivalrous, firms in different countries can use the same technology; but that idea will never produce the same good because of the Armington structure. Innovators receive payment for their diffused ideas, but imperfect enforcement of IPR implies that a fraction of these ideas may be imitated, resulting in no compensation for the innovators. To reduce the risk of imitation and increase the return on R&D, innovators file patent applications. As patenting is a costly activity, innovators choose to patent only a share of their technologies, arriving at an interior solution that weights the benefits and costs of patenting.

Innovation and International Diffusion. Innovators in n create new technologies at the rate $\gamma_{nt} \left(\frac{H_{nt}}{Y_{nt}} \right)^\eta$, with H_{nt} representing investment into R&D. Assuming full depreciation of new technologies, the number of newly created technologies every period is

$$Z_{nt} = \gamma_{nt} \left(\frac{H_{nt}}{Y_{nt}} \right)^\eta, \quad (7)$$

where γ_{nt} is a time-varying country-specific parameter capturing the innovation efficiency, and the parameter η represents diminishing returns to R&D investment.

Technology Diffusion. In every period t , a fraction $\varepsilon_{in,t}$ of ideas created by country n diffuses to each other country i . Diffusion increases the likelihood that an idea is used to

produce differentiated intermediate goods. The number of intermediate goods produced in country n , with domestic and foreign technology, at time t is equal to:

$$T_{nt} = \sum_{i=1}^M \varepsilon_{ni,t} Z_{it}.$$

Cross-border patenting. Innovators receive payments from producers who use their technology, but diffused ideas can be imitated, resulting in zero payments. Due to diffusion and imitation, innovators in country n decide on the fraction of their innovations to patent in each country i . Unpatented ideas are imitated with certainty, while a fraction $(1 - \phi_{in,t})$ of patented ideas from country n are imitated in country i , with $\phi_{in,t}$ representing the bilateral strength of IP protection. This term can be influenced by several factors, such as bilateral or multilateral agreements on IPR protection, harmonization of IP laws and enforcement practices, and explicitly addressed responsibilities in technology transfer agreements or licensing contracts (Santacreu, 2022; Hémous et al., 2023). Faster diffusion and better IP protection increase patenting activity, but patenting is costly.

Innovators from country n choose the fraction $\lambda_{in,t}$ to patent in country i at time t to maximize

$$\underbrace{\lambda_{in,t} V_{in,t}^{\text{pat}} - C(\lambda_{in,t}) P_{it}}_{\text{Value of patenting}} + \underbrace{(1 - \lambda_{in,t}) V_{in,t}^{\text{nopat}}}_{\text{Value of not patenting}},$$

where $C(\lambda_{in,t})$ is the cost of patenting a technology from country n into country i . We assume that the cost of patenting is paid in the destination country i .²²

The value of a patented technology is given by:

$$V_{in,t}^{\text{pat}} = \varepsilon_{in,t} \phi_{in,t} \frac{\Pi_{it}}{T_{it}}, \quad (8)$$

where Π_{it} are the profits of all intermediate goods produced in country i and $\phi_{in,t}$ is the share of patented technologies from country n that are imitated in country i . We assume

²²Patents are national rights granted by individual countries' patent offices, and the associated fees, translation costs, local representation expenses, and enforcement costs are all incurred within the jurisdiction of the destination country.

that $V_{in,t}^{nopat} = 0$, that is, all unpatented technologies are imitated.

The FOC for the share of patented technologies is:

$$C'(\lambda_{in,t})P_{it} = V_{in,t}^{pat} - V_{in,t}^{nopat}.$$

We assume the following functional form for the cost of patenting:

$$C(\lambda_{in,t}) = \frac{1}{\xi} \tau_{in} (\lambda_{in,t})^\xi, \quad \xi > 1, \quad (9)$$

where τ_{in} captures bilateral patenting frictions that increase the cost of patenting, such as language, geography, and ξ captures increasing marginal costs to patenting.

This functional form incorporates curvature to ensure an interior solution for the share of diffused ideas that are patented. The underlying assumption is the presence of increasing marginal costs associated with patenting additional technologies; that is, increasing efforts to patent more technologies—more legal and administrative tasks, higher complexity, and higher R&D demands, particularly when overseeing an extensive patent portfolio—incur disproportionately greater resources. In other words, we assume congestion in the patenting process.

We can then express the share of patented technologies as

$$\lambda_{in,t} = \tau_{in}^{-1/(\xi-1)} \left(\frac{V_{in,t}^{pat}}{P_{it}} \right)^{1/(\xi-1)}. \quad (10)$$

Note that if there is no IP protection, i.e., $\phi_{in,t} = 0$, the patent share ($\lambda_{in,t}$) is 0. This means that when imitation is guaranteed to occur, firms have no incentive to patent their innovations, as they would not be able to protect their IP and capture the full value of their invention. However, when there is perfect IP enforcement, that is, if $\phi_{in,t} = 1$, the patent share ($\lambda_{in,t}$) is not necessarily 1. This is because patenting is costly, and firms must weigh the benefits of patenting against the associated costs.

Then, the number of patented technologies is

$$\text{Pat}_{in,t} = \lambda_{in,t} \varepsilon_{in,t} Z_{nt}. \quad (11)$$

Substituting equations (8) and (10) into (11), we obtain an expression for the determinants of cross-border patenting:

$$\text{Pat}_{in,t} = \tau_{in}^{-1/(\xi-1)} \varepsilon_{in,t} (\varepsilon_{in,t} \phi_{in,t})^{1/(\xi-1)} \left(\frac{\Pi_{it}}{T_{it} P_{it}} \right)^{1/(\xi-1)} Z_{nt}. \quad (12)$$

Optimal R&D investment decisions The first-order condition for R&D investment is derived from the following problem:

$$Z_{nt} V_{nt} - P_{nt} H_{nt}, \quad (13)$$

subject to the expression for $Z_{nt} = \gamma_{nt} \left(\frac{H_{n,t}}{Y_{nt}} \right)^\eta$. The value of innovation can be expressed as

$$V_{nt} = \sum_{i=1}^M \varepsilon_{in,t} \lambda_{in,t} \phi_{in,t} \frac{\Pi_{it}}{T_{it}}. \quad (14)$$

The first-order-condition determining R&D investment is

$$H_{nt} = \eta \frac{V_{nt}}{P_{nt}} Z_{nt}. \quad (15)$$

Proposition 1. (*Structural Gravity for Cross-border Patents.*) Equation (12) provides a structural gravity equation for cross-border patents. Cross-border patenting from country n to country i at time t is given by

$$\text{Pat}_{in,t} = \underbrace{(\tau_{in})^{-1/(\xi-1)}}_{\text{Bilateral patenting frictions}} \underbrace{(\phi_{in,t})^{1/(\xi-1)}}_{\text{IPR enforcement}} \underbrace{\varepsilon_{in,t}^{\frac{\xi}{\xi-1}}}_{\text{Diffusion}} \underbrace{\left(\frac{\Pi_{it}}{P_{it} T_{it}} \right)^{1/(\xi-1)}}_{\text{Destination Attractiveness}} \underbrace{\frac{H_{nt} P_{nt}}{\eta V_{nt}}}_{\text{Source innovation}}. \quad (16)$$

Cross-border patent flows obey the law of gravity, i.e., the “closer” and the “larger” two countries are, the more cross-border patents they would exchange.

More specifically, according to our theoretical gravity model, cross-border patenting depends on several determinants. First, they depend on the characteristics of the origin country, $\frac{H_{nt}P_{nt}}{\eta V_{nt}}$, which reflects the source country’s innovative capacity. Second, they depend on the characteristics of the destination country, $\left(\frac{\Pi_{it}}{P_{it}T_{it}}\right)^{1/(\xi-1)}$, which determine the attractiveness of the host country, based on size and productivity. Finally, they depend on country-pair specific characteristics, $(\tau_{in})^{-1/(\xi-1)}(\phi_{in,t})^{1/(\xi-1)}\varepsilon_{in,t}^{\frac{\xi}{\xi-1}}$, which are influenced by three key factors: time-invariant bilateral patenting frictions (e.g., distance, language), diffusion forces, and trade and patenting policies (e.g., international agreements and treaties, harmonization of patent laws).

The gravity equation for cross-border patenting shares some similarities with the gravity equation for trade flows, but also exhibits important differences. The determinants of bilateral patent flows in our gravity equation include bilateral patent frictions, technology diffusion barriers, trade and patent-related policies, the attractiveness of the destination market, and the innovation capacity of the source country. However, unlike the gravity equation for trade flows, the outward multilateral resistance term only indirectly enters our system through trade in intermediates. This difference can be attributed to the non-rival nature of patents, which allows for the simultaneous use of a patented invention in multiple countries. Consequently, the decision to patent in a particular market is less influenced by the relative barriers to patenting in other markets. Instead, it depends on factors such as market size, the strength of IP protection, and the potential for local enforcement. In contrast, the presence of outward multilateral resistance terms in the gravity equation for trade flows captures the idea that exports to one country come at the opportunity cost of not exporting to other markets, as determined by the relative trade barriers across destinations.

Finally, the profits are given by

$$\Pi_{nt} = (\bar{m} - 1)W_{nt}L_{nt}. \quad (17)$$

Preferences. In each country, there is a representative consumer choosing consumption to maximize lifetime utility

$$\sum_{t=0}^{\infty} \beta^t C_{nt}, \quad (18)$$

where β is the discount factor, C_{nt} is consumption of country n in period t .

Consumers face the budget constraint

$$P_{nt}C_{nt} = W_{nt}L_{nt} + \Pi_{nt}^{all}, \quad (19)$$

where Π_{nt}^{all} are profits of all firms operating in the economy.

Market Clearing Conditions. To close the model, we impose the following market clearing conditions:

- (i) Final output: $Y_{nt} = C_{nt} + H_{nt}$;
- (ii) Labor market: $\bar{m}W_{nt}L_{nt} = \sum_{i=1}^M \pi_{in,t}Y_{it}$;
- (iii) Total number of intermediate goods produced using domestic and foreign technology: $T_{nt} = \sum_{i=1}^M \varepsilon_{ni,t}Z_{it}$;
- (iv) Consumer's budget constraint: $P_{nt}C_{nt} = W_{nt}L_{nt} + \Pi_{nt}^{all}$ where Π_{nt}^{all} includes the profits of intermediate producers and innovators, and it is defined in Appendix A.

Mechanism of the Model. The key interaction that determines cross-border patenting in the model is between the diffusion of ideas, $\varepsilon_{in,t}$, and the quality of IP enforcement in each country, $\phi_{in,t}$.

This interaction is captured by equation (12), which describes the number of patented technologies. A higher value of $\varepsilon_{in,t}$ indicates greater diffusion of ideas from country n to country i . The term $\phi_{in,t}$ captures the quality of IP enforcement.

The interaction between $\varepsilon_{in,t}$ and $\phi_{in,t}$ determines the incentives for innovators in country n to patent their ideas in country i . When diffusion ($\varepsilon_{in,t}$) is high, innovators

have a greater incentive to patent their ideas in country i to protect their IP and receive payments for the use of their technology. However, the strength of this incentive also depends on the level of IPR enforcement ($\phi_{in,t}$).

If IPR enforcement is weak (i.e., $\phi_{in,t}$ is low), the risk of imitation is high, and innovators from n may be less inclined to patent their ideas in country i , even if diffusion is high. Conversely, if IPR enforcement is strong (i.e., $\phi_{in,t}$ is high), innovators may have a greater incentive to patent their ideas in country i , as the risk of imitation is lower.

The model also captures the cost of patenting through equation (9). This equation implies that the cost of patenting increases with the share of patented technologies (λ), and the parameter ξ determines the curvature of the cost function. As the cost of patenting increases, innovators may be less willing to patent their ideas, even if diffusion and IPR enforcement are high.

The interplay between diffusion, IPR enforcement, and the cost of patenting determines the equilibrium level of cross-border patenting in the model. This equilibrium is characterized by equation (10).

This equation shows that the share of patented technologies ($\lambda_{in,t}$) depends on the value of a patented technology ($V_{in,t}^{pat}$) relative to the price level in country i , (P_{it}). The value of a patented technology, in turn, depends on the profits in country i (Π_{it}), the number of technologies in country i (T_{it}), and the probability of not being imitated ($\phi_{in,t}$).

In summary, the mechanism of the model revolves around the interaction between diffusion ($\varepsilon_{in,t}$) and IPR enforcement ($\phi_{in,t}$) in determining the incentives for cross-border patenting. Higher diffusion encourages patenting, while stronger IPR enforcement reduces the risk of imitation, further incentivizing patenting. However, the cost of patenting acts as a counterbalancing force, reducing the willingness of innovators to patent their ideas. The equilibrium level of cross-border patenting is determined by the interplay of these factors, as captured by the key equations of the model, (9), (10), and (12).

3.2 Estimating Gravity for Cross-border Patent Flows

The objective of this section is to set an econometric model for cross-border patent flows. Guided by our theory (as summarized by equation (16)) and capitalizing on developments from the gravity literature on trade, migration, and FDI, we specify the following estimating equation:

$$\begin{aligned} \text{Pat}_{ni,t} = & \exp[\chi_{i,t} + \pi_{n,t} + \vec{\mu}_{ni} + BRDR_{ni,t} \times \beta \\ & + POLICY_{ni,t} \times \alpha] \times \epsilon_{ni,t}, \forall i, n. \end{aligned} \quad (20)$$

The dependent variable in equation (20), $\text{Pat}_{ni,t}$, denotes the total number of patents from source i to destination n at time t .²³ To take full advantage of our dataset and to improve estimation efficiency, we allow for patent flows from any source i to any destination n .

Since our dependent variable is based on count data, Poisson is the natural choice for our estimator. Moreover, owing to the seminal work of Santos Silva and Tenreyro (2006), the Poisson Pseudo Maximum Likelihood (PPML) has become the workhorse estimator for trade gravity models because of two properties that also apply to our analysis of patent flows. First, due to its multiplicative form, the PPML estimator would enable us to include and take advantage of the information contained in the zeros in our sample; i.e., when there is no patent flow from a given country to another. Second, and probably more important, Santos Silva and Tenreyro (2006) demonstrate that the PPML estimator successfully handles heteroskedasticity in trade flows data, which, due to Jensen's inequality, actually renders the corresponding OLS estimates inconsistent.²⁴

In addition to cross-border ($i \neq n$) patent flows, our dependent variable also includes domestic ($i = n$) patents. This is important for our analysis for two related reasons. First, the use of domestic patents will enable us to estimate the impact of (de-)globalization, defined broadly as the effects of factors not explicitly captured in our model, on inter-

²³In the robustness analysis, we also obtain estimates at the industry level.

²⁴We refer the reader to Santos Silva and Tenreyro (2021) for a recent summary and discussion of the benefits of PPML for gravity regressions. We view PPML as the appropriate estimator for our purposes. Therefore, we employ it to obtain our main results. However, in the robustness analysis, we also replicate our main findings with the OLS estimator.

national relative to domestic patent flows. To capture such effects, we introduce to our specification a series of time-varying border indicators, which are defined and discussed in more detail below. In addition, the use of domestic patents will enable us to obtain estimates of the globalization effects for different groups of countries (e.g., poor vs. rich, or South vs. North in our notation), country-specific globalization effects (e.g., for China vs. US), and directional estimates of the effects of globalization (e.g., for patents moving from North to South, from North to North, etc.). The latter is particularly important for our purposes because we would be able to isolate the impact of globalization on cross-border patent flows from North to South.²⁵

Turning to the variables on the right-hand side of our estimating equation, specification (20) includes three sets of fixed effects. The term $\chi_{i,t}$ denotes a full set of source-time fixed effects, which are motivated by and would absorb the theoretical term $\frac{P_{it}H_{it}}{\eta V_{it}}$. In addition, these fixed effects will control for and absorb any other source-time-specific characteristics (e.g., institutional quality, national regulations, taxes, etc.) that may impact patent flows. Similarly, $\pi_{n,t}$ denotes a full set of destination-time fixed effects, which are motivated by the theoretical term, $\left(\frac{\Pi_{nt}}{P_{nt}T_{nt}}\right)^{1/(\xi-1)}$, and will control for and absorb any other destination-time-specific characteristics that may impact patent flows. In combination, $\chi_{i,t}$ and $\pi_{n,t}$ will comprehensively account for all possible country-time characteristics on the source and the destination side, thus enabling us to focus on the bilateral determinants of cross-border patents, which are of central interest to us.

The third set of fixed effects that we employ includes country-pair fixed effects, $\vec{\mu}_{ni}$, which also vary depending on the direction of the patent flows. The use of bilateral fixed effects would, of course, also absorb the theoretical constant term $\left(\frac{\mu}{\rho}\right)^{-1/(\xi-1)}$. Motivated by Baier and Bergstrand (2007), and consistent with the average treatment effect methods of Wooldridge (2010), country-pair fixed effects are typically used in trade gravity models to mitigate potential endogeneity concerns with bilateral policies. The same logic should hold for bilateral policies that impact cross-border patents. On a related note, the country-pair fixed effects would absorb and comprehensively control for all time-

²⁵We refer the reader to Yotov (2022) for a summary of the benefits of using domestic flows in trade gravity regressions.

invariant bilateral patent frictions that are part of the theoretical term $(\tau_{ni})^{-\frac{1}{\xi-1}}$.²⁶

We also allow for the pair fixed effects in our model to vary depending on the direction of the patents. Baier, Yotov, and Zylkin (2019) demonstrate that this has significant implications for the estimates of free trade agreements, which can be very asymmetric and biased if the pair fixed effects are not allowed to vary depending on the direction of trade flows. Applied to our setting, the use of directional pair fixed effects could be crucial for proper identification of the impact of globalization and liberalization policies for the directional patent flows from North to South.

The next term in specification (20) is particularly important for our analysis. Specifically, $BRDR_{ni,t}$ denotes a vector of time-varying border indicators, which take a value of one for international patents and are equal to zero for domestic patents for each year in our sample. The estimates on these dummy variables would capture the impact of globalization, trends that have affected the flow of cross-border patents relative to domestic patents. The flexible definition of the border dummies would enable us to identify the common (across countries) impact of globalization as well as the effects of globalization for specific groups of countries and depending on the direction of patent flows (e.g., from North to South). Bergstrand, Larch, and Yotov (2015) demonstrate that failure to control for such globalization effects may result in severely biased estimates of the effects of trade agreements in gravity regressions (e.g., because they may erroneously capture globalization trends). This may also be the case for the effects of policies that target cross-border patents. Moreover, it is possible that the evolution of cross-border patent flows may be driven by factors beyond the observable covariates in our model. As demonstrated in our empirical analysis, the flexible specification with borders would enable us to account for such effects.

²⁶Egger and Nigai (2015) and Agnosteva, Anderson, and Yotov (2019) demonstrate that the ‘standard’ gravity variables (e.g., distance, contiguity, common official language, etc.) do well in predicting relative bilateral trade costs, however, they fail to capture the level of bilateral trade costs (e.g., they underpredict the bilateral trade costs for the poor countries and overpredict them for the more developed countries). Therefore, and given our focus on the time-varying bilateral determinants of patent flows, we will rely on a specification with country-pair fixed effects to obtain our main results. Nevertheless, we will start the empirical analysis by estimating our model with a set of ‘standard’ gravity variables instead of the country-pair fixed effects. On the one hand, this will provide benchmark estimates for the effects of the standard gravity variables on cross-border patents. In addition, we will be able to benchmark our findings against those from the trade gravity literature to explore similarities and differences.

Before we continue to describe the rest of the covariates in specification (20), we discuss two technical items in relation to the globalization dummies in our model. First, we cannot obtain estimates of the impact of globalization without the domestic patents in our sample. If we only had international patents, then the impact of globalization would be controlled for but buried in the country-time fixed effects. Second, due to perfect collinearity with the pair fixed effects in our preferred specification, we cannot estimate all border effects, so we need to drop one of them. Our choice will be the border dummy for the first year in our sample, 1995. Thus, all globalization effects that we will obtain would be relative to those in 1995.

In addition to accounting for globalization trends, we also include in our econometric model several policy variables that were designed to affect international patent flows. Specifically, the vector $POLICY_{ni,t}^k$ in equation (20) includes the following time-varying bilateral policy covariates. $RTA_{in,t}$ is an indicator variable that takes a value of one if countries i and n have a regional trade agreement (RTA) in force at time t .²⁷ In addition, we rely on Martínez-Zarzoso and Chelala (2021) to distinguish between RTAs with and without technology provisions ($RTA_TECH_{in,t}$ vs. $RTA_NO_TECH_{in,t}$, respectively). $TRIPS_{in,t}$ is an indicator for the TRIPS agreement, which has been built using the information provided at the WTO website.²⁸ Since the generated TRIPS dummy variable is almost collinear with WTO membership, we include only the former in the empirical specification. Finally, $PCT_{in,t}$ is an indicator for membership in the Patent Cooperation Treaty (PCT).²⁹ Similar to our treatment of the effects of globalization, we would allow

²⁷Data on RTAs have been updated using the code provided by de Sousa (2012), who coded free-trade agreements using WTO data and complementary national sources.

²⁸The agreement states that developing countries and those in the process of transformation from a centrally-planned into a market economy would have a five-year transition period, until 2020. Least-developed countries (LDC) were granted a longer transition period of a total of eleven years (until 1 January 2006), with the possibility of an extension. The transition period has been extended three times, and now runs until 1 July 2034, or until a member ceases to be an LDC, whichever comes first.

²⁹The PCT is an international treaty concluded in 1970, which was amended in 1979 and modified twice (in 1984 and 2001) and with 157 members in 2022. The members can obtain patent protection simultaneously in all Contracting States by filing and international patent application in the country of which the applicant is a national or resident and it can also be filled in the International Bureau of WIPO. Additionally, it can also be filled in the European Patent Office (EPO), the African Regional Intellectual Property Organization (ARIPO), the African Intellectual Property Organization (OAPI) or the Eurasian Patent Office (EAPO) if countries are members of the agreements and conventions related to each of those patent offices. See <https://www.wipo.int/treaties/en/registration/pct> for further information.

for heterogeneous effects of each of the policy variables in our model depending on the direction of patent flows (e.g., from North to South).

Finally, following the standard approach in the gravity literature, in our main specifications we cluster the standard errors by country pair, i.e., $Cov[\varepsilon_{int}, \varepsilon_{ind}] \neq 0$ for all t, d , and zero elsewhere. However, motivated by Egger and Tarlea (2015) and Pfaffermayr (2019), in the robustness analysis we also experiment with three-way clustering by source, destination, and year.

4 Estimation Results and Comparative Statics

This section presents the findings from our estimation analysis (in Subsection 4.1) and discusses comparative statics results (in Subsection 4.2).

4.1 Estimation Results

This subsection reports our main findings regarding the impact of various determinants of the flow of patents across international borders, including standard gravity variables, globalization, and various bilateral policies. To highlight several important aspects of our data and identification strategy, we develop the analysis in four specifications, which are nested in equation (20). We start with simple cross-section specifications with standard gravity variables for various years. Second, we allow for the effects of globalization to vary based on development levels and depending on the direction of patents (e.g., from North to South). Third, we move to a panel model, which enables us to comprehensively account for all time-invariant bilateral patent frictions while obtaining heterogeneous estimates of the impact of globalization on cross-border patent flows. Fourth, in addition to the heterogeneous globalization effects, we introduce a set of policy variables and allow for their effects to be heterogeneous across the same dimensions as the globalization effects. We conclude the estimation analysis with a series of sensitivity experiments, which are designed to test the robustness of our main findings to alternative estimators and specifications, to generate richer policy implications, and to highlight the sectoral

dimension of our new database. While our dataset covers the period from 1980 onward, the empirical analysis focuses primarily on the years from 1995 to 2018. This is due to the limited coverage and reliability of the data on cross-border patent flows and other key variables of interest in the earlier years of the sample period.

Our first estimates are obtained from the following naïve cross-section version of specification (20), which only includes exporter and importer fixed effects as well as a set of ‘standard’ time-invariant gravity variables:

$$\begin{aligned} \text{Pat}_{ni} = & \exp[\beta_1 LN_DIST_{ni} + \beta_2 CNTG_{ni} + \beta_3 LANG_{ni} + \beta_4 CLNY_{ni}] \times \\ & \exp[\beta_5 BRDR_{ni} + \chi_i + \pi_n] \times \epsilon_{ni}, \quad \forall i, n. \end{aligned} \quad (21)$$

Here, following the trade gravity literature, LN_DIST_{ni} is the log of population-weighted bilateral distance between countries n and i , and $CNTG_{ni}$, $LANG_{ni}$, and $CLNY_{ni}$ are indicator variables that capture the presence of a common border, common official language, and any type of colonial relationships between n and i , respectively. Finally, $BRDR_{ni}$ is a dummy variable, which takes a value of one for international transactions, and it is equal to zero otherwise. By construction, $BRDR_{ni}$ will capture the average impact of any bilateral factors (apart from those included explicitly in our model, e.g., geography) that drive a wedge between cross-border patent flows and domestic patent flows.

Despite its simplicity, specification (21) will serve three important purposes. First, it will deliver estimates of the effects of the ‘standard’ gravity variables with our new bilateral patent data, which can serve as a reference for future studies, depending on their purposes. Second, on a related note, we will be able to compare our estimates of the effects of the ‘standard’ gravity variables on patent flows with those from the trade literature. Finally, we will obtain from specification (21) an estimate of the ‘border’ effects for the first year in our sample, which we will combine with the ‘globalization’ effects from our preferred panel specification to perform some counterfactual analysis.

Our first set of results appears in Table 2. The estimates in column (1) correspond

directly to specification (21) and they are obtained with data for the first year in our sample – 1995. We note the following. First, the estimate of the effect of distance is negative and statistically significant but much smaller than the corresponding effect for trade flows. Given the nature of the patent flows, we find this result to be intuitive. Second, the estimates on $CNTG_{ni}$ and $CLNY_{ni}$ are not statistically significant, which is another difference from the corresponding trade estimates. Third, we obtain a positive, statistically significant, and very large (much larger than the corresponding index for trade) estimate of the effect of common language ($LANG_{ni}$) on cross border patent flows. We find the results that language is a strong determinant of cross-border patent flows and that its effects are much stronger than those for trade, intuitive as well.

Finally, we obtain a very large, negative, and statistically significant estimate of the impact of borders on the cross-border patent of trade flows. Specifically, our estimate suggests that, conditional on geography (i.e., distance and contiguity), common language, and colonial relationships, other border frictions in place have decreased cross-border patent flows by about 91 percent (std.err. 3.31) in 1995.³⁰ While it is true that some of these frictions can probably never be eliminated, our estimates suggest that the frictions in cross-border patent flows are very large and, relatedly, that there is significant scope for potential gains from further regional and global integration.

The results in column (2) of Table 2 are obtained after a single modification to the specification from column (1). Specifically, motivated by our theory, we allow for heterogeneous border effects depending on countries’ development level and on the direction of patent flows. To this end, we use the 2000 version of the income classification of the World Bank (WB) to categorize the countries in our sample in two groups – “North”, which includes the “high-income” countries and the “upper-middle income” countries from the WB classification vs. “South”, which includes the “lower-middle income” countries and the “low income” countries from the WB classification.³¹ Then, based on the

³⁰Calculated as $[\exp(-2.404) - 1] * 100 = -90.97$, where the standard errors are obtained with the Delta method.

³¹We chose the 2000 WB classification for two reasons (an alternative classification was built for 1990). First, because it is more complete. For instance, using data from 1990 fails to capture the emergence of post-Soviet countries like Russia, Ukraine, and the Baltic states. Second, because the year 2000 is closer to the middle of our sample. The classification can be downloaded at this link:

Table 2: Gravity Estimates for Patent Flows

	(1)	(2)	(3)	(4)
	1995	1995	2006	2018
LN_DIST	-0.350 (0.072)**	-0.418 (0.075)**	-0.314 (0.071)**	-0.218 (0.071)**
CNTG	-0.186 (0.223)	-0.370 (0.231)	-0.458 (0.268) ⁺	-0.682 (0.333)*
LANG.	1.403 (0.202)**	1.313 (0.187)**	1.315 (0.198)**	1.363 (0.161)**
CLNY	0.025 (0.270)	-0.120 (0.282)	-0.430 (0.246) ⁺	-0.359 (0.234)
BRDR.	-2.404 (0.366)**			
BRDR_N_N		-1.939 (0.391)**	-1.736 (0.356)**	-2.023 (0.360)**
BRDR_N_S		-3.050 (0.497)**	-2.851 (0.661)**	-2.893 (0.843)**
BRDR_S_S		-4.440 (0.553)**	-4.724 (0.570)**	-4.401 (0.334)**
BRDR_S_N		-5.740 (0.667)**	-3.741 (0.790)**	-3.253 (0.814)**
<i>N</i>	2326	2326	2782	2488

This table reports estimates of the effects of the ‘standard’ gravity variables on cross-border patent flows. The estimates are obtained from specification (21). The dependent variable in each specification is the number of patent applications and the estimator is PPML. The results in column (1) are for 1995. The estimates in column (2) allow for the effects of international borders to vary across four bilateral groups (including “North to South”, “South to South”, “North to North”, and “South to North”, which are based on the income classification of the World Bank for 2000. Finally, the results in columns (3) and (4) replicate the estimates from column (2) but for the years 2006 and 2018, respectively. Standard errors in parentheses are clustered by country pair. ⁺ $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

two country-specific income groups (“North” vs. “South”) and the direction of patent flows, we construct four bilateral income groups of countries, which allow for heterogeneous border effects depending on whether the patent flows are from “North to North” (*BRDR_N_N*), “North to South” (*BRDR_N_S*), “South to South” (*BRDR_S_S*), and “South to North” (*BRDR_S_N*). Thus, in effect, we split the common border effect from column (1) into four categories.³²

We draw three conclusions based on the results from column (2) of Table 2. First, the effects of the borders are very large regardless of the direction of cross-border patent flows. Second, the border effects are heterogeneous across the four groups in our specification. Perhaps not surprisingly, the smallest border estimates are for flows from “North to North”. The combination of strong institutions and closer economic ties among the developed countries is a natural explanation for this result. The largest estimates are for patent flows from “South to North”, followed by the estimate on flows from “South to South”. The main conclusion that we draw based on these results is that the single border effects from column (1) has masked significant heterogeneity, which may have strong implications for development and inequality. Finally, we note that the rest of the gravity estimates in column (2) are not statistically significantly different from those in column (1).

The results in columns (3) and (4) of Table 2 replicate the results from column (2) but for the mid-year (2006) and for the last year in our sample (2018), respectively. The idea is to offer some preliminary evidence for the evolution of the gravity estimates during the period of investigation. Most estimates remain stable, e.g., for common language, colonial ties, borders between ‘North to North’, ‘North to South’, and ‘South to South’. However, we also observe three interesting patterns. First, we see that the estimates on distance have fallen over time. This is consistent with the latest trade estimates and the notion

<https://datacatalogfiles.worldbank.org/ddh-published/0037712/DR0090754/OGHIST.xlsx>. In the robustness analysis, we also experiment with two alternative classifications. First, we use all possible income groups categories. We prefer the two-group approach for expositional purposes and because it is consistent with our empirical results. Second, we define “South” differently by only including the low income countries in this category.

³²We also obtained group-specific estimates, i.e., for the impact of globalization on the countries in the North vs. South. The results are consistent with but less informative than our main estimates (since they do not distinguish between the direction of the patent flows).

that the world has become flatter. Second, we note that the effects of contiguity remain negative but increase in absolute value and become statistically significant. Comparative advantage in the development of patents is the natural explanation for this result. Finally, we see that the estimates of the border effects for cross-border patent flows from ‘South to North’ have fallen over time in absolute value. This is an interesting pattern, which should be interpreted with caution due to the possible omission of potentially important control variables in our specification. We take a step to address this concern by estimating the following econometric model:

$$\begin{aligned} \text{Pat}_{ni,t} = & \exp[\chi_{i,t} + \pi_{n,t} + \vec{\mu}_{ni} + \sum_{t=1996}^{2018} \beta_t^{N,N} \times \text{BRDR_N_N}_{ni,t} + \sum_{t=1996}^{2018} \beta_t^{N,S} \times \text{BRDR_N_S}_{ni,t}] \times \\ & \exp[\sum_{t=1996}^{2018} \beta_t^{S,N} \times \text{BRDR_S_N}_{ni,t} + \sum_{t=1996}^{2018} \beta_t^{S,S} \times \text{BRDR_S_S}_{ni,t}] \times \epsilon_{ni,t}, \quad \forall i, n. \end{aligned} \quad (22)$$

Specification (22) is a panel model, where we have replaced the standard time-invariant bilateral gravity variables with directional country-pair fixed effects ($\vec{\mu}_{ni}$). In addition, we allow for time-varying border effects, which will capture the impact of globalization forces on cross border patent flows over time for each of the four groups of countries in our sample.³³ Due to perfect collinearity with the country-pair fixed effects in our model, we cannot estimate all border/globalization effects for each group of countries and need to drop one of them for each group. Our choice is to drop, for each group, the border dummy for the first year in our sample, 1995. Thus, each of the globalization effects that we obtain would be relative to the corresponding effect for the same group in 1995.

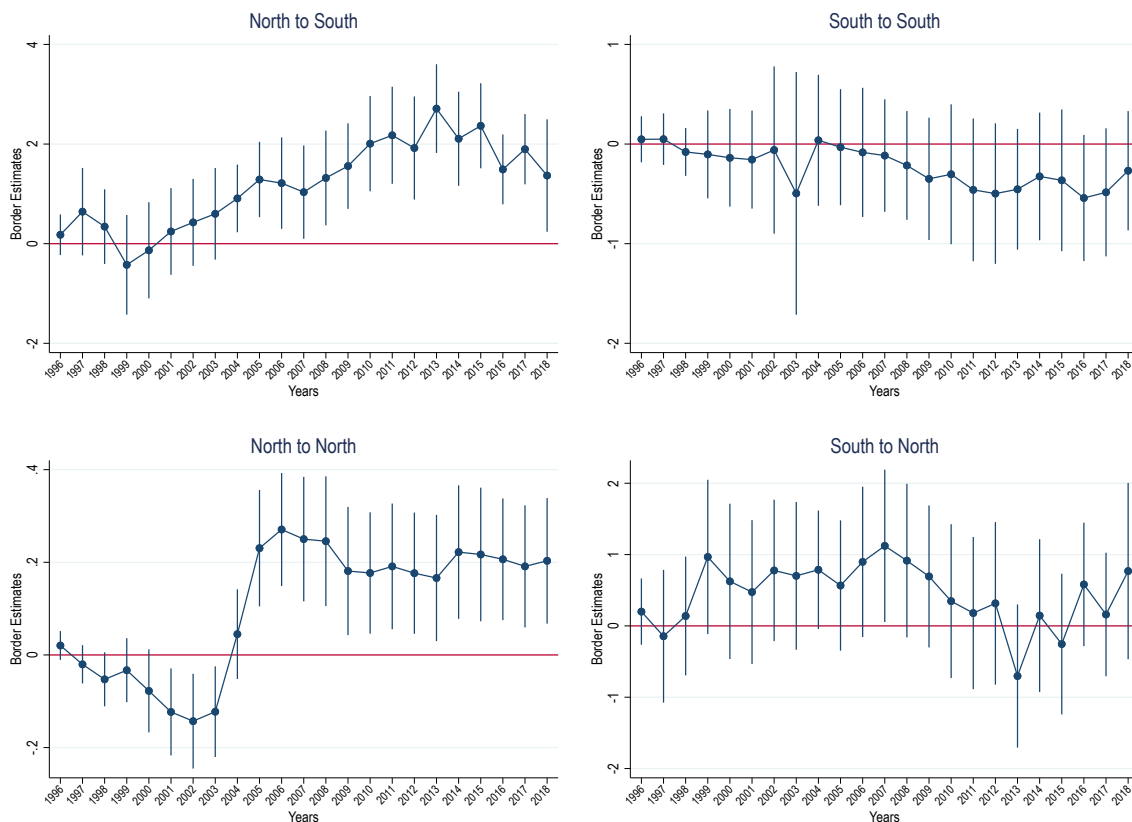
For expositional purposes (e.g., due to the large number of border estimates that we obtain), instead of using a tabular format, we report our findings in Figure 10. The figure reveals several interesting patterns across and within the four groups of estimates. First, the impact of globalization has been the strongest for patent flows from ‘North to South’.

In terms of magnitude, our estimates suggest that globalization forces have led to an

³³The four sets of ‘globalization’ dummy variables in specification (22) are essentially time-varying border variables for each year and each group of countries in our sample. The country-pair fixed effects in our setting will fully control for all time-invariant bilateral characteristics that impact cross-border patent flows. Thus, our globalization estimates will be all-inclusive measures of the effects of time-varying bilateral factors that drive a wedge between domestic and cross-border patent flows. In a subsequent specification, we will isolate the effects of bilateral policies.

increase of about 300 percent in the patent flows from ‘North to South’ during the period of investigation.³⁴ This result justifies our main focus on the cross-border patent flows from ‘North to South’. We also see a de-globalization trend for this group post-2013.

Figure 10: Globalization and North-South Cross-border Patenting



Note: This figure reports estimates of the impact of globalization on cross-border patent flows for four bilateral groups of countries, including “North to South” (top left panel), “South to South” (top right panel), “North to North” (bottom left panel), and “South to North” (bottom right panel). The country groups are based on the income classification of the World Bank, and all estimates are obtained from a single regression, which is based on specification (21) after allowing for heterogeneous effects for each of the four bilateral groups. See text for further details.

The second largest impact of globalization on cross-border patent flows is for the group ‘North to North’. The impact of globalization for this group follows an interesting pattern, where the overall increase in patent flows is exclusively driven by a very large increase during the period between 2002 and 2006. Further investigation of the drivers of the large increase in the early 2000s reveals that most of the ‘jump’ is due to the

³⁴Calculated as $[exp(1.368) - 1] * 100 = 292.69$, where the 1.368 is the estimate on $BRDR_N_S_{ni,t}$ that we obtain in 2018, which, by construction, captures the total globalization effects for this group during the period of investigation.

large cross-border patent flows from and to Korea and toward Germany and the United States.³⁵ Finally, we see from the two right panels of Figure 10 that globalization has not benefited cross-border patents originating from the South, neither toward other ‘South’ countries nor toward the ‘North’. These results are in sharp contrast to our findings from the top left panel of the figure, but they are consistent with our findings from the data.

The next specification delivers our main estimation results, which are obtained from specification (22), where, in addition to allowing the impact of globalization to be heterogeneous across the four bilateral income groups from our previous specification, we also introduce a series of policy variables, which we expect may affect cross-border patents. Specifically, we estimate the effects of RTAs, which may or may not include technology provisions, the effects of the TRIPS agreement, and the effects of PCTs. Similar to the analysis of the effects of globalization, we also allow for heterogeneous effects of each of the policy variables across the four bilateral income groups in our sample. To detect possible correlations between the different policies and to decompose their effects, we introduce them sequentially in the four columns of Table 3. The estimates in each column are obtained with the full set of heterogeneous border variables and the full set of fixed effects from specification (22). The dependent variable is always the number of patent applications, the estimator is PPML, and the standard errors are clustered by country pair.

The estimates in column (1) of Table 3 reveal that, overall, RTAs have been effective in promoting cross-border patent flows. We also note that the RTA effects have been quite heterogeneous across the four bilateral income groups in our sample.³⁶ The estimates of the RTA effects that we obtain are positive for each of the four groups, and they are statistically significant for flows from ‘North to North’, which is the largest estimate, and from ‘South to North’, which is a bit smaller but still sizable.

³⁵We prove this in the Appendix, where we reproduce the bottom-left panel of Figure 10 after dropping the observations for cross-border patent flows from and to Korea and toward Germany and the United States.

³⁶The heterogeneous estimates that we obtain suggest that imposing common policy effects may lead to misleading policy implications. We offer such estimates in the robustness analysis in the Supplementary Appendix, where we also investigate the impact on the policy estimates from the use of domestic patent flows and from accounting for globalization forces.

Table 3: Preferential Agreements and Cross-border Patents

	(1)	(2)	(3)	(4)
	RTA	TECH	TRIPS	PCT
RTA_S_N	0.175 (0.064)**			
RTA_S_S	0.132 (0.315)			
RTA_N_N	0.239 (0.044)**			
RTA_N_S	0.074 (0.056)			
RTA_TECH_S_N		0.196 (0.053)**	0.201 (0.052)**	0.196 (0.053)**
RTA_TECH_S_S		0.098 (0.344)	0.188 (0.376)	-0.212 (0.278)
RTA_TECH_N_N		0.221 (0.043)**	0.209 (0.041)**	0.208 (0.042)**
RTA_TECH_N_S		0.081 (0.055)	0.078 (0.055)	0.078 (0.055)
RTA_NO_TECH_S_N		-0.675 (0.932)	-0.666 (0.910)	-0.690 (0.881)
RTA_NO_TECH_S_S		0.080 (0.358)	0.104 (0.364)	-0.193 (0.321)
RTA_NO_TECH_N_N		1.178 (0.159)**	1.159 (0.155)**	1.157 (0.155)**
RTA_NO_TECH_N_S		-0.147 (0.159)	-0.147 (0.156)	-0.139 (0.157)
TRIPS_S_N			0.211 (0.178)	0.219 (0.178)
TRIPS_S_S			0.502 (0.228)*	0.514 (0.207)*
TRIPS_N_N			0.209 (0.126)+	0.210 (0.126)+
TRIPS_N_S			0.051 (0.157)	0.032 (0.157)
PCT_S_N				0.637 (0.444)
PCT_S_S				1.271 (0.319)**
PCT_N_N				0.177 (0.083)*
PCT_N_S				-0.041 (0.221)
<i>N</i>	63846	63846	63846	63846

This table reports estimates of the effects of preferential agreements on cross-border patent flows. The estimates are obtained from specification (20), after allowing for the effects of globalization to vary across four bilateral groups (including “North to South”, “South to South”, “North to North”, and “South to North”, which are based on the income classification of the World Bank. In addition, each column of the table introduces a new policy variable, whose effects are also allowed to vary across the four bilateral income groups. Specifically, column (1) accounts for RTAs. Column (2) distinguishes between the effects of RTAs with and without technology provisions. In column (3) we add the TRIPS variables. Finally, in column (4), we also introduce the effects of the PCT. The dependent variable in each specification is the number of patents and the estimator is PPML. Standard errors in parentheses are clustered by country pair. + $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

The results in column (2), where we distinguish between the effects of RTAs with and without technology provisions, reveal further heterogeneity. The estimates of the effects of RTAs with technology provisions that we obtain are also positive for all groups but, once again, these agreements have benefited patent flows from ‘North to North’ and from ‘South to North’. According to our estimates, the patent flows from “North to North” have benefited tremendously from the RTAs without technology provisions, while the effects of this type of agreements have not been significant for the other three groups in our sample.

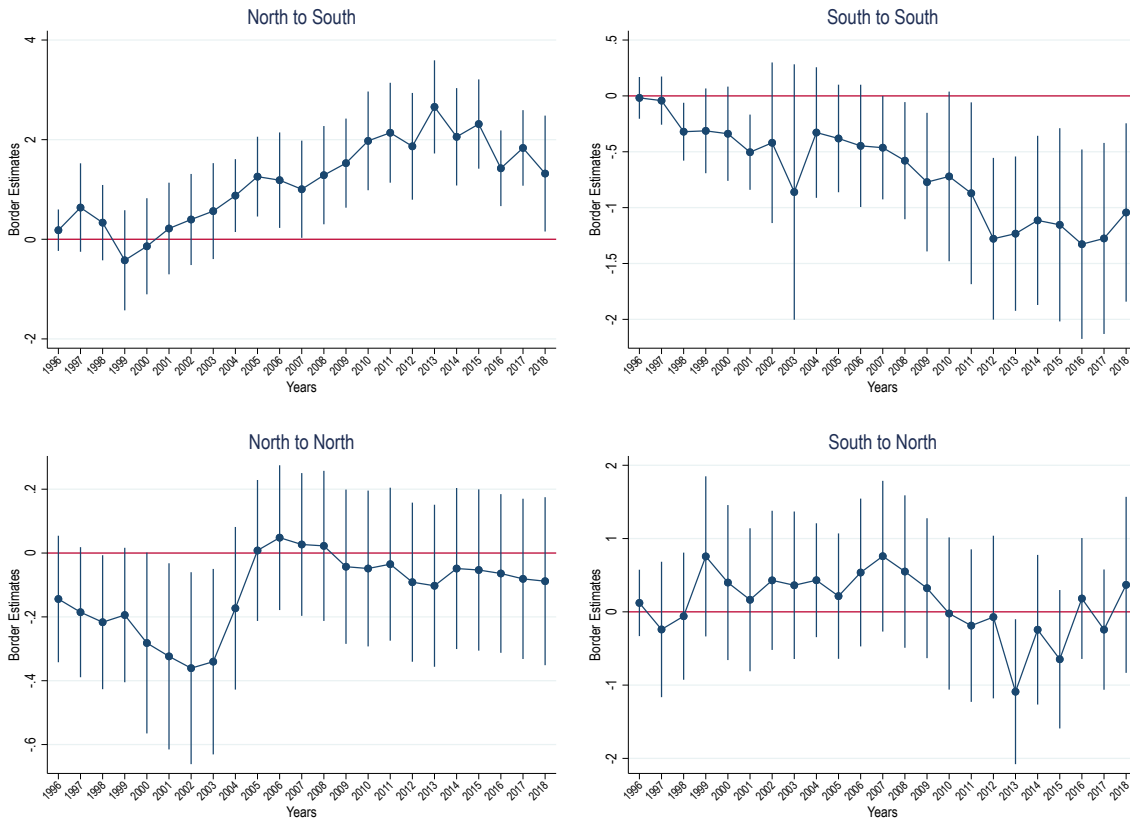
In columns (3) and (4) of Table 3, we sequentially introduce the effects of the TRIPS agreement (in column (3)) and, in addition, the effects of the Patent Cooperation Treaty (PCT) (in column (4)). Since the introduction of the additional policy variables in each column does not significantly affect the estimates of the variables that were already included in our specification, we focus our discussion on the results from column (4), which presents our main and most comprehensive findings.

The estimates of the effects of RTAs with and without technology provisions are almost unchanged. According to our estimates, TRIPS has led to more patent flows from ‘South to South’ and, to a lesser degree, from ‘North to North’, while the effects for the other two groups are not statistically significant. Similarly, the PCT has been very effective in promoting patent flows from ‘South to South’, followed by ‘North to North’. The estimate for flows from ‘South to North’ is also positive, but it is not statistically significant. Finally, the PCT has not been effective in promoting flows from ‘North to South’.

Figure 11 reproduces the results from Figure 10 for the impact of globalization on cross-border patent flows for the four bilateral income groups of countries in our sample. However, the new globalization estimates are obtained from the econometric specification from column (4) of Table 3, which also includes the full set of our policy variables. Thus, the new globalization effects that we visualize in Figure 10 are stripped from the policy effects that we just discussed.

We draw two conclusions based on the estimates from Figure 11. First, and most

Figure 11: Globalization, Policy, and North-South Cross-border Patenting



Note: This figure reproduces the results from Figure 10 for the impact of globalization on cross-border patent flows for the four bilateral income groups of countries in our sample. However, the new globalization estimates are obtained from the econometric specification from column (4) of Table 3, which also includes the full set of our policy variables. See text for further details.

important for our purposes, the estimates of the impact of globalization on the patent flows from ‘North to South’ (in the top-left panel of Figure 11) remain strong. Comparison between the corresponding results for this group between Figures 11 and 10 reveals that the agreements we account for have contributed very little to explain the globalization effects in Figure 10. Thus, most of these globalization effects, as well as their evolution over time, remain almost unchanged in Figure 11 and, therefore, cannot be attributed to the policy variables in our model. This reinforces our decision to allow for and retain the flexible border variables in our main specification.

Second, we see that the globalization effects are significantly different for the other three groups in our analysis. The overall gains for the “North to North” group from Figure 10 have disappeared in Figure 11. However, in the early 2000s, we still see the strong

impact of globalization forces that are not captured explicitly in our model. The main conclusion from the top-right panel of Figure 11 is that without the policies from Table 3 in place the cross-border patent flows from “South to South” would have decreased over time. Thus, even though the net globalization effects that we captured in Figure 10 were not significant, policy has indeed been effective to counter the decreasing trend in patent flows for this group. Finally, most estimates for the “South to North” group (bottom right panel) remain not statistically significant, reinforcing our conclusion that the policies in our model have not been effective to stimulate patent flows from “South to North”.

We conclude this section with a brief discussion of the results from the robustness experiments that we perform to test the sensitivity of our main findings and to highlight some additional dimensions of our new database. The corresponding estimates, along with a more detailed discussion, appear in the Supplementary Appendix. We reproduce our results: (i) Applying the OLS estimator. (ii) Using three-way clustering. (iii) Not controlling for the impact of globalization explicitly. (iv) Excluding domestic patents. Importantly, in this setting we cannot estimate the effects of globalization. (v) Leaving out China from our estimating sample. (vi) Using an alternative definition for “North” vs. “South”. Specifically, we defined “South” as including only the “low” income countries and “North” for all other countries. (vii) Using patent citations to construct a new, quality adjusted measure of cross-border patents, which is used as our dependent variable. (viii) Imposing common effects across the different income groups for each of the policy variables in our model. (ix) Not using pair fixed effects in order to be able to identify the effects of “standard” gravity variables in the panel specification. (x) We also reproduced our main results at the sectoral level too. Overall, our main conclusions are reinforced by the additional experiments that we performed, but we also observed some intuitive heterogeneity. Our estimates, along with a corresponding discussion are included in the Appendix.

4.2 Cross-border Patenting, Development, and Inequality

Our empirical results indicate that globalization forces have been important drivers of cross-border patenting, especially from North to South. To the extent that cross-border patenting helps with technology transfer, these trends could be increasing income per capita in South and have an impact on inequality. In this section, we study, through the lens of our model, the influence of globalization on cross-border patenting, innovation, and development. Building upon the main estimates presented earlier, we conduct a counterfactual exercise to address the following questions: What would have been the trajectory of cross-border patenting from North to South between 1995 and 2018 if globalization trends had remained at their 1995 levels?, and What are the implications for global income inequality? The model is solved period by period.

Calibration. To answer these questions, we employ our comprehensive dataset on patenting, geographical factors, and R&D intensity to calibrate our model. We use data for 42 countries for the period 1995 to 2018, due to data availability on R&D spending. We partition the countries into two groups belonging to North and South.³⁷

Several parameters are calibrated from previous studies or taken directly from the data. The parameter of the Armington elasticity takes a value of 5, which implies a trade elasticity of 4, as is standard in the trade literature. The parameter for the elasticity of innovation is set to 0.5, which is consistent with previous studies in the literature (see Cai, Li, and Santacreu, 2022). Population is taken from the CEPII database. The iceberg transport costs and productivity parameters are calibrated using data on trade flows, geography measures, Gross Domestic Product (GDP) and population from CEPII, and deploying gravity methods using PPML. The elasticity of patenting costs is set to $\xi = 2$, so there are increasing marginal costs of patenting. We calibrate $\varepsilon_{in,1995}$ using

³⁷The countries that belong to the North are: Australia (AUS), Austria (AUT), Belgium (BEL), Canada (CAN), Switzerland (CHE), Germany (DEU), Denmark (DNK), Spain (ESP), Finland (FIN), France (FRA), United Kingdom (GBR), Greece (GRC), India (IND), Ireland (IRL), Israel (ISR), Italy (ITA), Japan (JPN), Netherlands (NLD), Norway (NOR), New Zealand (NZL), Portugal (PRT), Singapore (SGP), Sweden (SWE), United States (USA); the countries that belong to South are: Argentina (ARG), Brazil (BRA), Chile (CHL), China (CHN), Colombia (COL), Ecuador (ECU), Hong Kong (HKG), South Korea (KOR), Lithuania (LTU), Mexico (MEX), Malaysia (MYS), Peru (PER), Philippines (PHL), Poland (POL), Slovakia (SVK), Thailand (THA), Turkey (TUR), Uruguay (URY).

the estimates from the cross-section gravity equation of cross-border patents in Table 2. We set $\phi_{in} = 0.25$, which implies that innovators receive 25 percent of profits from foreign adopters (Santacreu, 2021) (except for the South, which only pays one-tenth of that amount to the North). We set $\phi_{ii} = 0.5$ so that domestic innovators and domestic adopters split the surplus equally. Table 4 reports the parameter values.

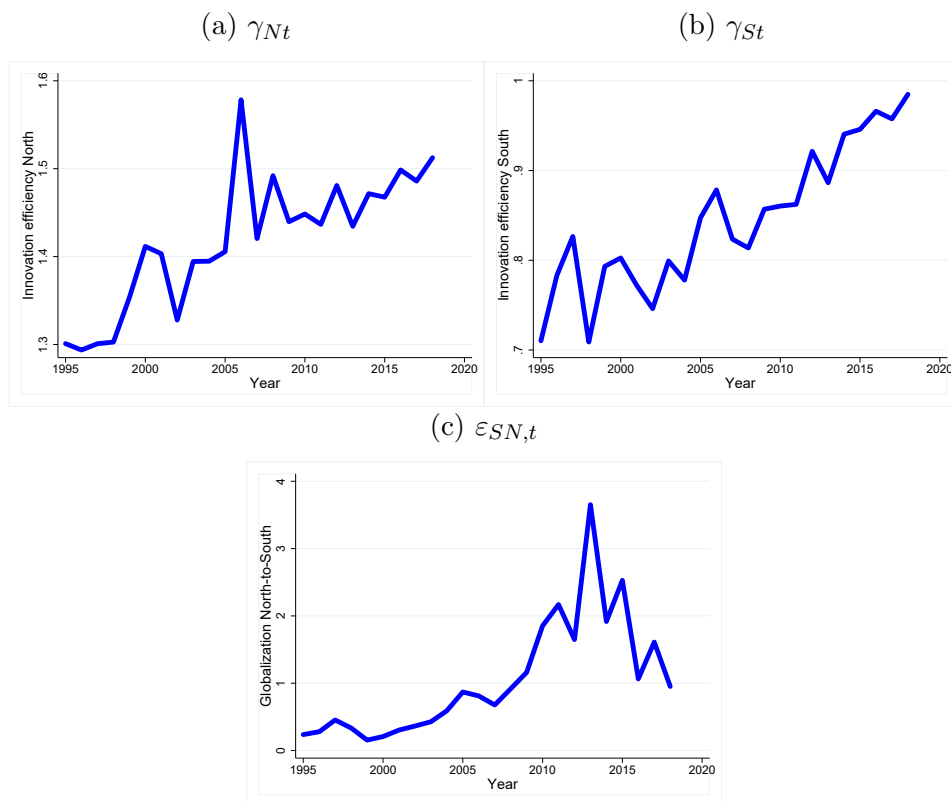
Table 4: Parameter Values

Parameter	Value	Description
σ	5	Armington elasticity
d_{NS}	6.6024	Iceberg trade costs from S to N
d_{SN}	6.1284	Iceberg trade costs from N to S
η	0.5	Elasticity of innovation
L_N	0.71	Population N
L_S	1	Population S
ξ	2	Elasticity in the cost of patenting
ϕ_{SN}	0.25	Santacreu (2022)
ϕ_{NS}	0.025	Santacreu (2022)
ϕ_{NN}	0.5	Santacreu (2022)
ϕ_{SS}	0.5	Santacreu (2022)
ε_{NS}	0.48	Gravity 1995
ε_{SN}	0.52	Gravity 1995
ε_{NN}	1	Gravity 1995
ε_{SS}	1	Gravity 1995

The remaining parameters, namely, the innovation efficiency, γ_{nt} , and the diffusion forces, reflected in $\varepsilon_{SN,t}$ in equation (12), are calibrated to match data on R&D intensity and the border effect obtained from our main specification in column (4) of Table 3 and Figure 11. We then feed the sequence of border effects into $\varepsilon_{SN,t}$, which captures globalization effects in equation (12), and leave the others constant throughout the period, since globalization (diffusion) forces for the other pairs of regions have remained stable over the period of analysis.

We calibrate γ_{nt} to match data for R&D intensity. The calibrated parameters are reported in Figure 12. Throughout the analyzed period, there has been an increase in innovation efficiency in the South relative to North corresponding with a rise in R&D investment in South relative to North.

Figure 12: Calibrated Parameters



Notes: The figure plots the parameters γ_{nt} which we calibrate to match the data from R&D intensity, and $\varepsilon_{SN,t}$, which we have reported in Figure 10.

Untargeted Moments. To validate our model, we evaluate its performance in fitting two variables that were not explicitly targeted during the calibration process: the number of patents (Z_{Nt}) and the share of cross-border patent applications ($\lambda_{SN,t}$). The correlation between the share of patented technologies from North to South in the model and the corresponding share in the data is approximately 0.82. Furthermore, the correlation between the ratio of patents in South to North in the data and the corresponding ratio in the model ($\frac{Z_{St}}{Z_{Nt}}$) is approximately 0.83. Moreover, the model and data consistently show an increasing trend in the ratio of patents in South relative to North, which aligns with the observed increase in relative R&D intensity in the South. Finally, our model can capture, on average, about 60% of patent applications from North to South from the data.

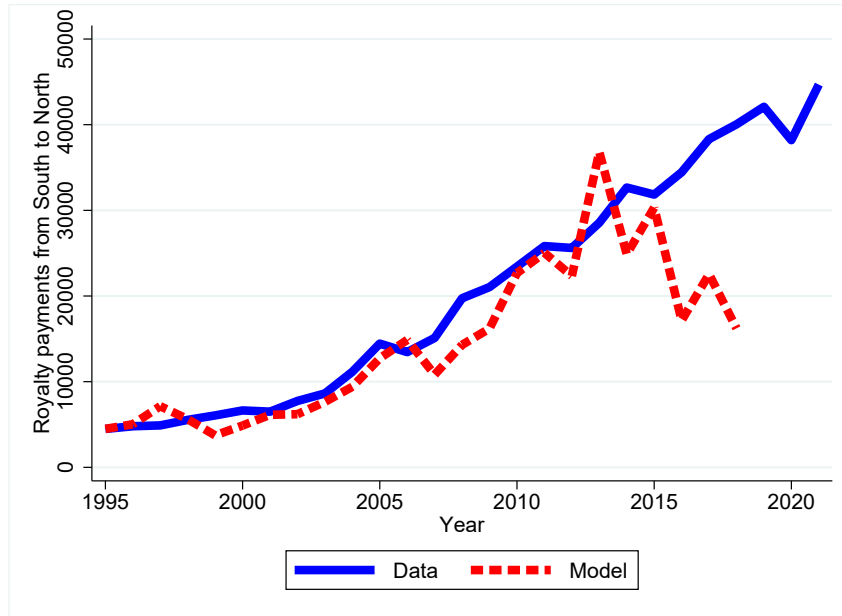
External Validation. While our model is not explicitly calibrated using data on royalty payments, it can replicate the evolution of royalty flows from developing (South) to developed (North) countries over the period from 1995 to 2018. Figure 13 plots the royalty payments from South to North as predicted by the model alongside empirical data on these flows.³⁸ The model closely tracks the substantial rise in royalty payments to developing countries that occurred over this period.

Importantly, the model is able to reproduce not just the overall growth trend, but also key fluctuations seen in the data, such as the noticeable dip and recovery between 2000 and 2005. It is worth noting that while the model successfully captures the overall trend and key fluctuations in royalty payments up to the late 2010s, there is some divergence between the predicted and actual values in the final few years of the analysis period. Specifically, the model appears to underestimate the royalty flows observed in the empirical data for 2020.

The close match between the model’s predictions and the data royalty payment evolution serves as external validation.

³⁸Data are from from the OECD-WTO Balanced Trade in Services (BaTIS) dataset for 1995-2012 and combined with that for 2005-2021.

Figure 13: Royalty payments from South to North, 1995-2018 (million USD)

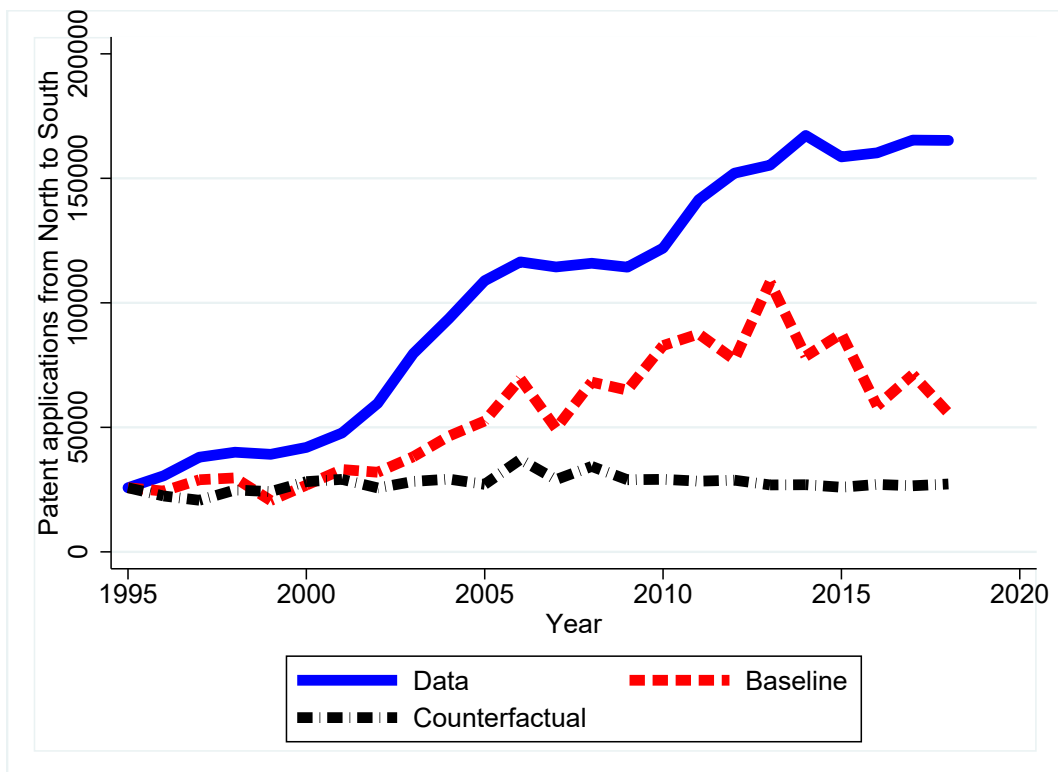


The figure shows royalty payments from South to North between 1995-2018 as predicted by the model and in the data. Data from the OECD-WTO Balanced Trade in Services (BaTIS) dataset.

Counterfactual Analysis: Cross-border Patenting and Income per Capita Differences. We proceed with our main counterfactual analysis, relying on the estimates of globalization effects on patent flows from “North to South.” We simulate a scenario without globalization forces by using the estimated vector of globalization trends from 1995 to 2018 as our baseline and setting all border estimates to their corresponding 1995 values. Our findings, summarized in Table 5, suggest that in the absence of globalization trends, cross-border patenting would have been significantly lower. On average, cross-border patenting would have been 38 percent lower between 1995 and 2018 in the absence of the observed globalization trends. This effect is particularly pronounced after 2000, with cross-border patenting from North to South being 46 percent lower in the absence of globalization forces (see Figure 14).

We complete the analysis by examining changes in income per capita differences between South and North, computed as the ratio of income per capita in South relative to that of North, between our baseline and our counterfactual where globalization forces remain at 1995 levels. In the absence of globalization effects, income inequality would

Figure 14: Cross-border Patenting from North to South



Notes: The figure shows the evolution of cross-border patenting between 1995 and 2018 in the data (solid line), the baseline model incorporating globalization forces (dashed line), and the counterfactual without globalization forces (dotted-dash line).

have been 12.6 percent higher. This reduction in income inequality can be understood through the lens of two key variables: $\varepsilon_{SN,t}$, which represents the diffusion of ideas from the North to South, and $\phi_{SN,t}$, which captures the strength of IP protection in South for innovations originating in the North.

First, an increase in $\varepsilon_{SN,t}$ directly facilitates more technology transfer from the North to South by increasing the diffusion of ideas. Second, it indirectly promotes more technology transfer by encouraging more R&D investment and patenting in the North, as innovators seek to take advantage of the increased value of patenting in South. South benefits from more technology diffusion at the same price, while North benefits from increased royalty payments from more patents, which spurs further innovation and technology transfer to South.

The effect on income per capita differences depends on the interaction between $\varepsilon_{SN,t}$ and $\phi_{SN,t}$. An increase in $\varepsilon_{SN,t}$ reduces inequality if it dominates the rise in $\lambda_{in,t}$, which is determined by the level of $\phi_{in,t}$. A lower $\phi_{in,t}$ implies a smaller increase in $\lambda_{in,t}$ for the same increase in $\varepsilon_{in,t}$. In our case, the interaction between these two forces has led to a reduction in income per capita differences, highlighting the potential for globalization to have an inequality-decreasing effect. These effects are more pronounced after 2000, consistent with the empirical results displayed in Figure 11.

Table 5: Counterfactual Analysis: Cross-border Patenting, Globalization, and Income Inequality

	1995-2018	2000-2018
Cross-border patenting	38%	46%
Income pc differences	-12.6%	-15.6%

Note: The table shows changes in cross-border patenting from North to South and relative income per capita in South (relative to North) between a world with no globalization effects and one with globalization effects.

It is important to note that if globalization forces were primarily driven by improvements in IP enforcement through higher $\phi_{in,t}$, the effect on income inequality would likely have been an increase. This is because stronger IPR protection would enable innovators in North to charge a higher price for the technology transferred to South. As a result, a larger share of the technology transferred would be subject to royalty payments, effec-

tively increasing the cost of technology adoption for South. In this scenario, South would have to pay more for the same amount of technology transfer, leading to a widening of the income gap between North and South.

The results presented in Table 3 suggest that changes in trade and patenting policies during the period 1995-2018 have had a significant impact on cross-border patenting and, consequently, on income inequality between North and South. When we account for these policy changes in addition to the globalization and diffusion forces, we find that income inequality would have decreased by 10% between 1995 and 2018, and by 13% between 2000 and 2018. The estimates in Table 3 reveal that policy changes have been particularly effective in increasing cross-border patenting among North countries, with RTAs, TRIPS, and PCT membership all having significant positive effects on North-North patent flows. In contrast, these policies appear to have had limited impact on cross-border patenting from North to South, with the estimated coefficients being mostly non-significant for this direction of patent flows.

The asymmetric impact of policy changes on cross-border patenting has important implications for income inequality. When South countries patent in other South countries or in North countries, they receive royalty payments, which leads to an increase in income for South. Similarly, when North countries patent in other North countries, they receive royalty payments, leading to an increase in income for North. Given that North countries have higher innovation intensity, they tend to benefit more from these policy changes compared to South countries. As a result, income inequality between North and South decreases, but not to the same extent as it would have under globalization and diffusion forces alone. In summary, our findings highlight the role of globalization and cross-border patenting in promoting economic convergence and reducing global income inequality. The impact of globalization on cross-border patenting and inequality operates through changes in the diffusion of ideas ($\varepsilon_{SN,t}$) and the strength of IPR protection ($\phi_{SN,t}$). The ultimate effect on income per capita differences depends on the interaction between these two forces, with the potential for both inequality-increasing and inequality-decreasing outcomes. In our case, the interaction between $\varepsilon_{SN,t}$ and $\phi_{SN,t}$ has led to a reduction in

income per capita differences, as the inequality-decreasing effect of increased technology diffusion has dominated the inequality-increasing effect of higher technology prices.

5 Final Remarks

This paper empirically explores the drivers behind firms seeking international patent protection and links cross-border patenting to development. To this end, we compiled a new dataset on cross-border patenting across industries, enabling us to gain insights into global patenting behavior. To guide our analysis, we have developed a model that links globalization trends, trade policies, and cross-border patenting, emphasizing the importance of patent transfers from developed to developing countries. The model yields a structural gravity model, which we have estimated using the latest techniques from empirical trade literature, allowing us to account for the impacts of globalization and various policy factors.

Our analysis yields estimates of globalization effects that vary between North and South regions. Notably, globalization-driven patent flows from North to South have had a more favorable impact on the South after the 2000s, reducing global income inequality. Regarding policy variables, we find that RTAs play a role, especially those with IPR provisions that increase patent flows from North to South. Furthermore, both TRIPs and the PCT promote cross-patenting, though the impact varies depending on the groups of countries involved in the origin and destination of patent flows.

A counterfactual exercise shows that absent globalization forces, income per capita differences between North and South would have been larger, especially after 2000.

While our analysis focuses on the connection between globalization, trade policy and cross-border patenting, there may be other channels that influence firms' decisions to seek international patent protection, such as escape-competition motives or quality-signaling strategies. It would be interesting to explore the extent to which these channels influence firms' behavior and how they interact with regional trade agreements and IPR regimes. We leave these questions for future research.

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Supplementary Appendix

A Model equations

The endogenous variables are:

$$\{P_{it}, Y_{it}, W_{it}, p_{in,t}, x_{in,t}, \pi_{in,t}, H_{it}, Z_{it}, T_{it}, Z_{it}^W, \lambda_{in,t}, Pat_{in,t}, \Pi_{it}, \Pi_{it}^{all}, V_{in,t}^{pat}, V_{nt}\}$$

The parameters are:

$$\{\sigma, \gamma_n, \tau_{in}, \Omega_i, \xi, d_{in}, \eta\}$$

There us also a shock process: $\{\varepsilon_{in,t}\}$.

Resource constraint

$$Y_{nt} = C_{nt} + H_{nt}$$

Prices

$$P_{nt} = \left(\sum_{i=1}^M \Omega_i^{\sigma-1} T_{it} p_{ni,t}^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$$

Price intermediate goods

$$p_{in,t} = \bar{m} W_{nt} d_{in}$$

where $\bar{m} = \frac{\sigma}{\sigma-1}$

Demand intermediate goods

$$p_{in,t} x_{in,t} = T_{nt} \Omega_n^{\sigma-1} \left(\frac{\bar{m} W_{nt} d_{in}}{P_{it}} \right)^{1-\sigma} P_{it} Y_{it}$$

Trade share

$$\pi_{in,t} = \frac{\Omega_n^{\sigma-1} T_{nt} (W_{nt} d_{in})^{1-\sigma}}{\sum_{k=1}^M \Omega_k T_{kt} (W_{it} d_{ik})^{1-\sigma}}$$

Profits intermediate producers

$$\Pi_{nt} = \frac{1}{\sigma - 1} W_{nt} L_n$$

Number of intermediate goods

$$T_{nt} = \sum_{i=1}^M \varepsilon_{ni,t} Z_{it}$$

Number of ideas

$$Z_{nt} = \gamma_{nt} \left(\frac{H_{nt}}{Y_{nt}} \right)^\eta$$

FOC R&D

$$H_{nt} = \eta Z_{nt} \frac{V_{nt}}{P_{nt}}$$

Value of innovation

$$V_{nt} = \sum_{i=1}^M V_{in,t}^{pat}$$

Number of patented ideas

$$Pat_{in,t} = \lambda_{in,t} \varepsilon_{in,t} Z_{nt}$$

Share of patented ideas

$$\lambda_{in,t} = \tau_{in}^{-1/(\xi-1)} \left(\frac{V_{in,t}^{pat}}{P_{nt}} \right)^{1/(\xi-1)}$$

Value of a patented technology

$$V_{in,t}^{pat} = \varepsilon_{in,t} \phi_{in,t} \frac{\Pi_{it}}{T_{it}}$$

Budget constraint

$$P_{nt}C_{nt} = W_{nt}L_{nt} + \Pi_{nt}^{all}$$

- Profits of all firms

$$\Pi_{it}^{all} = \Pi_{it} - \sum_{n=1}^M \varepsilon_{in,t} \lambda_{in,t} \phi_{in,t} \frac{\Pi_{it}}{T_{it}} Z_{nt} + \sum_{k=1}^M \varepsilon_{ki,t} \lambda_{ki,t} \phi_{ki,t} \frac{\Pi_{kt}}{T_{kt}} Z_{it} - P_{it}H_{it}$$

B Additional Results

This appendix reports and discusses the results from a series of experiments we performed to test the robustness of our main findings and to highlight the dimensions of our new data. The experiments appear in the order in which they were mentioned in the main text. The first two experiments we perform are related to the heterogeneous estimates of the effects of globalization.

- In our first experiment we obtain directional globalization estimates based on all four income categories of the World Bank, including, “high income”, “upper-middle income”, “lower-middle income”, and “low income”. Figure A1 reports our estimates, which are intuitive and as expected. Most importantly, the strongest effects of globalization are from rich to poor countries. The relationship between these estimates and our main results is that the latter are essentially weighted averages of the results in Figure 10.
- In Figure A2 we reproduce our main results from Figure 10, but without allowing for directional effects, i.e., just for ‘North’ vs. ‘South’. The results are expected and are consistent with our main findings.

Table A1 shows the results for a number of robustness checks, obtained by estimating variations of the main empirical model from column (4) of Table 3. For clarity and expositional simplicity, we report only the globalization effects for “North” to “South” and the estimates from all specifications are included in a single Figure A3.

- The first variation consists of estimating a linear model using the natural log of patent counts as a dependent variable. As can be seen in column (1), the estimated coefficients for RTA present higher standard errors than for the PPML model with the dependent variable in levels. Nevertheless, the few coefficients that are accurately estimated present the same sign and similar magnitudes.
- The second column of Table A1 presents the results when standard errors are clustered by three dimensions: origin, destination, and time (instead of by pair). The statistical significance of the coefficients decreases slightly, but most interpretations remain valid.
- Column (3) shows the results when the model is estimated excluding the terms that proxy for globalization. In this case, the coefficients slightly change in magnitude compared with column (2) but remain within similar confidence bands.
- Column (4) excludes domestic patents, which results in lower coefficients for the RTA variables in the “North” to “South” group and slightly higher TRIPS coefficients, but the significance for the PTC vanishes. Importantly, this specification does not allow us to obtain estimates of any of the globalization effects that have been of central interest to us.
- Finally, column (5) shows the results excluding China, showing that this affects the significance for the SN policy variables, whereas coefficients for the North to North, and South to South pairs remain similar.

In Table A2 five additional robustness checks are presented.

- In column (1) a different classification of North and South is used, placing in South exclusively low-income countries, whereas North contains the other WB categories:

upper- and lower-middle- and high-income. While the RTA coefficients remain basically the same, a noticeable change in the TRIPS coefficients is that the SN group has a much higher coefficient than in the baseline classification that is now significant at the 1 percent level. The PCT coefficients lose significance with respect to the main specification.

- A common concern when analyzing patents trend is controlling for the quality of patents. There are some cases when patents might be filed en masse for reasons other than increasing innovation. For example, if a country improves its IPR quickly and significantly, it may cause a surge in patenting, as innovators rush to take advantage of this new IP protection. This could lead to a situation where the patenting activity of a country increases by much more than their innovation level would indicate. Another notable example would be the case of government subsidies for filed patents. This would incentivize the filing of many patents regardless of if they are actually of any merit. These factors make it important to consider the notion of “quality patents”; in other words, patents that are actually the result of innovation and result in a new useful knowledge base being created. This motivates our next experiment, in which we construct a quality-adjusted patent count.

There are many ways to adjust for quality, but we follow one of the methods developed by Coelli, Moxnes, and Ulltveit-Moe (2022) in which they look at the number of citations created as a share of the number of patents filed. We calculate this relative quality of patent flows as follows: Let c_p denote the number of citations that occur within the first three years after patent p was filed. Let μ_f be the average number of citations within the first three years after filing across that DOCDB family such that:

$$\mu_f = \frac{\sum_{p \in \Xi_{pf}} c_p}{\sum_{p \in \Xi_{pf}} p},$$

where Ξ_{pf} is the number of patents, p , in that DOCDB family, f . The sum of citations for each origin is then:

$$Q_{it} = \sum_{p \in \Xi_{pf}} \mu_f,$$

where Ξ_{ft} is the set of country i 's families filed in year t . The full average quality for origin i in year t is given by:

$$\hat{Q}_{it} = \frac{Q_{it}}{P_{it}},$$

where P_{it} is the total patents filed by country i in year t .

Our new estimates with the quality-adjusted dependent variable appear in column (2) of Table A2, and they show an increase in the statistical significance of the RTA coefficients for agreements between SS. The corresponding globalization effects for the group North to South are shown in the bottom-left panel in Figure A3, showing positive and significant effects for 2002 onward.

- Next, in column (3) the averaged result for each policy variable are shown, without considering the level of development of the pair or countries. The results indicate that, on average, the effect of having an RTA with or without technology provisions is positive, higher in magnitude for the second and more accurately estimated. However, an important message from these results, in combination with our main findings, is that the average agreement estimates are masking significant heterogeneity in the impact of policy on cross-border patent flows.
- Finally, in column (4) we replace the pair fixed effects with a set of “standard” gravity variables, including the logged distance between countries (weighted by population), which is allowed to have heterogeneous effects for domestic vs. international patents, and dummy variables for sharing a common border, having the same official language and a past or present or past colonial relationship. Consistent with the trade gravity literature, our estimates for cross-border patents reveal that cross-border patenting decreases with distance and increases when countries share an official language. In fact, the estimate on common official language is sig-

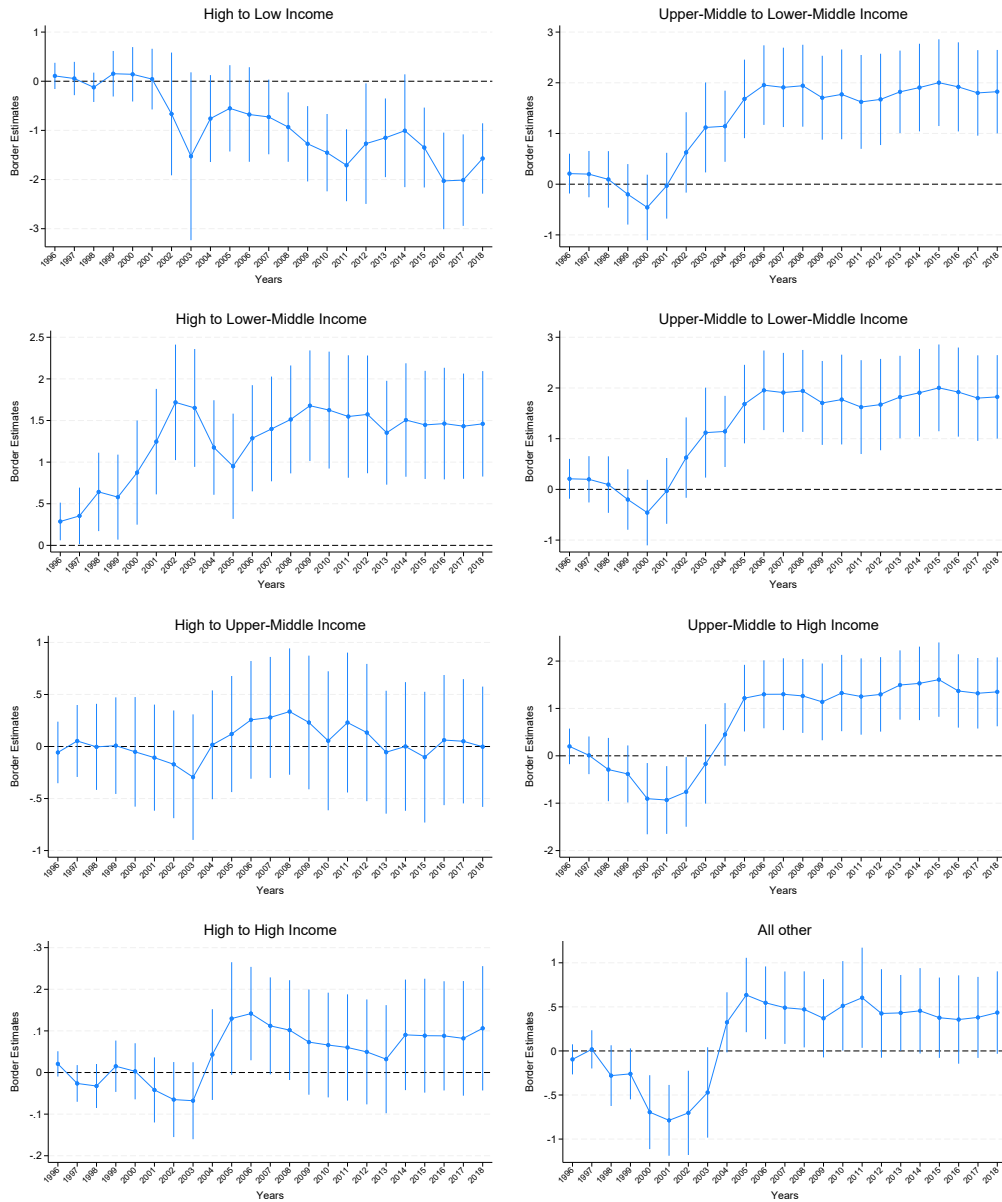
nificantly larger in magnitude than the standard estimate from the trade literature. We find this result intuitive, as language is potentially a more important factor for patent sharing.

We also obtain some results that are different from those for trade. For example, we obtain negative and significant estimates for the effects of common borders and colonial ties, while the corresponding estimates from the trade literature are mostly positive and statistically significant. The estimate for having ever had a colonial link is in accordance with the results obtained in the cross-sectional estimations in the main text. In addition, unlike the trade literature, we obtain a larger negative impact of domestic distance as compared to international distance. We are not aware of existing estimates of domestic distance for cross-border patents against which we can benchmark our findings. Although these results are not important for our main purposes, we find them interesting and possibly worth further investigation.

Finally, to highlight the sectoral dimension of our new dataset, we also obtain disaggregated estimates. Table A3 reports estimates at the sectoral level. Estimations are presented for all sectors in column (1) and for specific groups of manufacturing sectors, according to the Standard Industrial Classification Revision 3, in columns (2)-(5). The results shown in column (1) permit us to discard the existence of aggregation bias in our main results. In addition, results for specific groups of sectors are presented according to their level of sophistication. S1, S2 and S3 denote respectively sectors 15-19, 20-29 and 30-37, respectively. S1 includes food and beverages, tobacco, textile and apparel, leather and footwear; S2 includes paper and printing, chemicals and metals, among others; and S3 are office and computing machinery, communication equipment, vehicles and medical, precision and optical instruments, for example. The effect of RTA with technology provisions has a significantly higher magnitude for flows of patents going from North to North or to South in S3, whereas those without technology provision show a negative and weakly significant effect only for innovators in South patenting in North offices and for S3. The effect of other policy variables, TRIPS and PCT, do not vary much across sectors. Two main policy implications stand out from this analysis. First, the heterogeneity

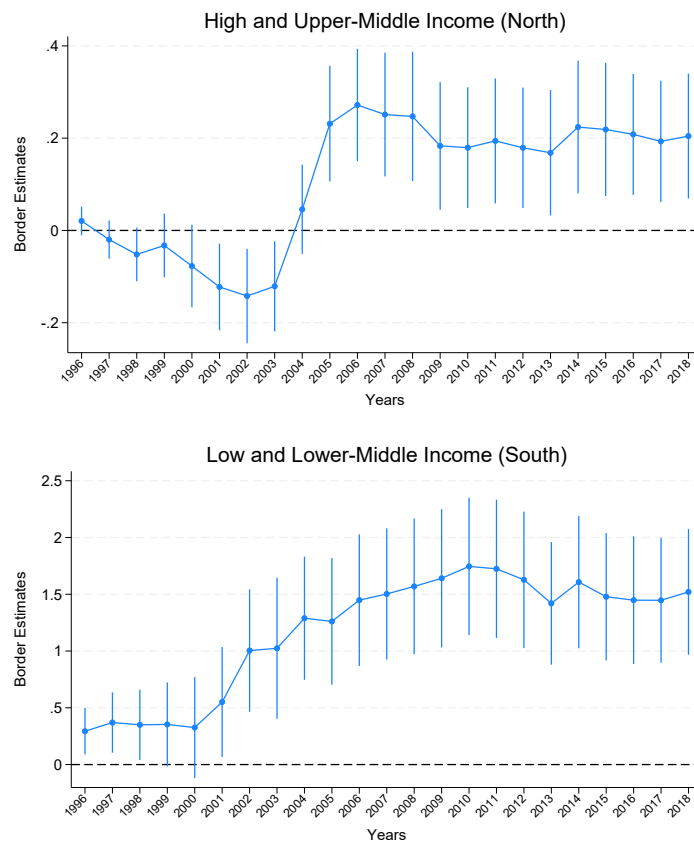
that we document across the broad sectors implies that serious policy analysis should be performed at the disaggregated level, potentially even more disaggregated than presented here (for which our data allow). Second, for RTA to facilitate/promote cross-patenting between rich and poor countries, the agreements must contain specific chapters on IPR and innovation.

Figure A1: Globalization and Cross-border Patenting, Directional



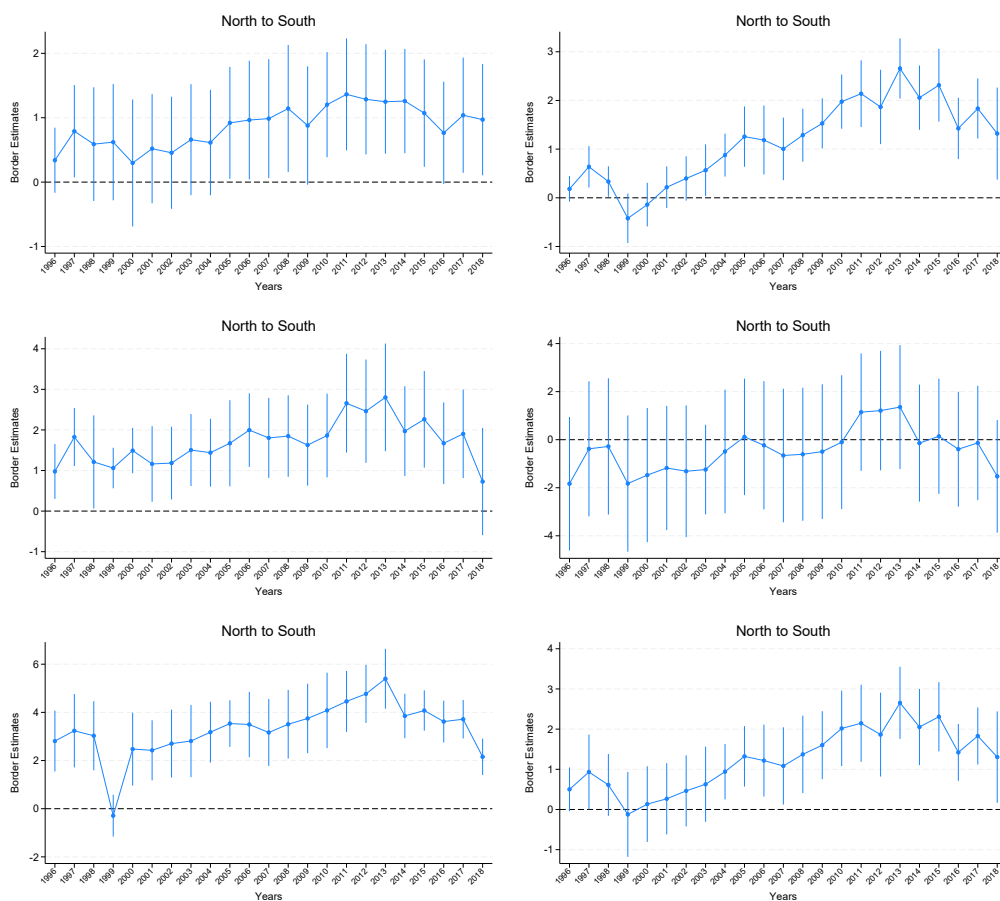
Note: This figure reproduces our main directional globalization estimates but based on the four income groups from the 2000 classification of the World Bank, including ‘high income’, ‘upper-middle income’, ‘lower-middle income’, and ‘low income’. All estimates are obtained from a single regression, which is based on specification (21) after allowing for heterogeneous effects for each of the four bilateral groups. See text for further details.

Figure A2: Globalization and Cross-border Patenting, North vs South



Note: This figure reproduces our main globalization estimates for the ‘North’ vs. ‘South’ group of countries but without allowing for directional effects. All estimates are obtained from a single regression, which is based on specification (21) after allowing for heterogeneous effects for each of the four bilateral groups. See text for further details.

Figure A3: Globalization and Cross-border Patenting, Robustness



Note: This figure reproduces our main directional globalization estimates for the group ‘North to South’ but based on the robustness checks presented in tables (A1) and (A2), including in this order from top to bottom and left to right: ‘OLS’, ‘CLUST’, ‘NOCHN’, ‘POOR’, ‘QALTY’ and ‘CMMN’. See the notes below tables (A1) and (A2) for further details. The graphs are obtained from from specification (20), after allowing for the effects of globalization to vary across four bilateral groups (‘North to South’, ‘South to South’, ‘North to North’, and ‘South to North’). See text for further details. Notice that only results for the first group are presented, since there were the only group showing significant effects, after including in the empirical model the policy variables.

Table A1: Preferential Agreements and Cross-border Patents: Robustness I

	(1)	(2)	(3)	(4)	(5)
	OLS	CLUST	NOGLOB	NODOM	NOCHN
rta_tech_S_N	0.031 (0.080)	0.196 (0.072)**	0.174 (0.058)**	0.218 (0.041)**	0.094 (0.087)
rta_tech_S_S	-0.104 (0.137)	-0.212 (0.233)	-0.515 (0.302) ⁺	-0.379 (0.317)	0.024 (0.297)
rta_tech_N_N	0.005 (0.039)	0.208 (0.071)**	0.236 (0.036)**	0.076 (0.036)*	0.224 (0.041)**
rta_tech_N_S	-0.034 (0.067)	0.078 (0.064)	0.084 (0.058)	0.004 (0.042)	0.032 (0.121)
rta_notech_S_N	0.059 (0.155)	-0.690 (0.919)	-0.501 (0.589)	-0.703 (0.801)	0.582 (0.230)*
rta_notech_S_S	-0.125 (0.244)	-0.193 (0.319)	-0.177 (0.298)	-0.179 (0.302)	-0.244 (0.299)
rta_notech_N_N	0.785 (0.087)**	1.157 (0.202)**	1.183 (0.157)**	0.814 (0.164)**	1.190 (0.154)**
rta_notech_N_S	0.178 (0.081)*	-0.139 (0.258)	-0.150 (0.152)	-0.210 (0.141)	0.078 (0.113)
trips_S_N	0.283 (0.100)**	0.219 (0.153)	1.004 (0.234)**	1.388 (0.208)**	0.325 (0.156)*
trips_S_S	0.320 (0.102)**	0.514 (0.262)*	-0.077 (0.186)	0.812 (0.229)**	-0.018 (0.133)
trips_N_N	0.140 (0.062)*	0.210 (0.219)	0.215 (0.081)**	0.285 (0.110)**	0.205 (0.125)
trips_N_S	0.215 (0.086)*	0.032 (0.172)	0.130 (0.179)	0.838 (0.220)**	-0.148 (0.129)
pct_S_N	0.010 (0.114)	0.637 (0.591)	0.947 (0.413)*	-0.196 (0.426)	0.799 (0.213)**
pct_S_S	-0.119 (0.143)	1.271 (0.575)*	0.800 (0.233)**	-0.256 (0.305)	1.786 (0.355)**
pct_N_N	0.345 (0.078)**	0.177 (0.078)*	0.174 (0.069)*	0.149 (0.126)	0.143 (0.081) ⁺
pct_N_S	0.024 (0.087)	-0.041 (0.384)	0.109 (0.230)	-0.452 (0.157)**	0.230 (0.159)
	(0.128)**	(0.038)**	(0.029)**	(0.126)**	(0.028)**
<i>N</i>	54334	63846	63846	62176	61229
<i>r</i> ²	0.931				

This table reports a number of robustness checks. The estimates are obtained from specification (20), after allowing for the effects of globalization to vary across four bilateral groups ('North to South', 'South to South', 'North to North', and 'South to North', which are based on the income classification of the World Bank. Each column of the table introduces a variation of the main model. Specifically, in column (1) uses a linear specification that is estimated by OLS with the dependent variable in natural logs. Column (2) clusters standard errors differently (multi-clustering). In column (3) the globalization effects are excluded from the specification. In column (4), estimates the model without domestic patents. Finally, column (5) excludes China from the sample. The dependent variable in each specification is the number of patents and the estimator is PPML in all but column (1). Standard errors in parentheses are clustered by country pair in all columns but . ⁺ $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Table A2: Preferential Agreements and Cross-border Patents: Robustness II

	(1)	(2)	(3)	(4)
	POOR	QALTY	COMMN	GRAV
rta_tech_S_N	0.188 (0.053)**	0.206 (0.077)**		-0.592 (0.354) ⁺
rta_tech_S_S	-0.452 (0.305)	-0.507 (0.193)**		1.281 (0.607)*
rta_tech_N_N	0.207 (0.041)**	0.113 (0.036)**		-0.535 (0.203)**
rta_tech_N_S	0.083 (0.055)	0.005 (0.046)		-0.609 (0.247)*
rta_notech_S_N	-0.540 (0.677)	0.269 (0.255)		-0.599 (0.374)
rta_notech_S_S	-0.223 (0.300)	0.024 (0.505)		1.191 (0.492)*
rta_notech_N_N	1.162 (0.155)**	1.047 (0.204)**		0.041 (0.197)
rta_notech_N_S	-0.148 (0.153)	-0.364 (0.173)*		-0.385 (0.233) ⁺
trips_S_N	0.897 (0.240)**	-0.174 (0.254)		1.694 (0.416)**
trips_S_S	-0.234 (0.235)	0.786 (0.248)**		-0.272 (0.312)
trips_N_N	0.191 (0.122)	0.112 (0.150)		0.366 (0.221) ⁺
trips_N_S	0.054 (0.182)	0.426 (0.252) ⁺		0.728 (0.360)*
pct_S_N	0.685 (0.455)	0.404 (0.164)*		-2.153 (0.712)**
pct_S_S	0.551 (0.342)	1.150 (0.336)**		-1.747 (1.238)
pct_N_N	0.167 (0.082)*	0.314 (0.106)**		-1.458 (0.362)**
pct_N_S	-0.043 (0.216)	-0.371 (0.171)*		-1.570 (0.714)*
rta_tech			0.171 (0.039)**	
rta_notech			0.739 (0.164)**	
trips			0.329 (0.185) ⁺	
pct			0.372 (0.120)**	
Indist_int				-0.563 (0.077)**
Indist_dom				-1.045 (0.127)**
contig				-0.632 (0.215)**
comlang				1.191 (0.159)**
comcolever				-0.606 (0.218)**
<i>N</i>	63846	60357	63846	65439

This table reports a number of robustness checks. The estimates are obtained from specification (20), allowing for the effects of globalization to vary across four bilateral groups ('North to South', 'South to South', 'North to North', and 'South to North', which are based on the income classification of the World Bank, in columns (1), (2) and (5). Each column of the table introduces a variation of the main model. Specifically, column (1) uses a different classification of North and South countries, with South including only low income countries. Column (2) uses as dependent variable the number of patents weighted by the number of citations. In column (3) we present average common effects of the policy variables. In column (4), we introduce "gravity" variables: the natural log of distance weighted by population (distinguishing between international and domestic distance), common border, common language and past or present colonial link; instead of pair FE. Finally, column (5) introduces the same "gravity" variables in the model that allows for heterogeneous effects. The dependent variable in all specifications but (2) is the number of patents and the estimator is PPML in all columns. Standard errors in parentheses are clustered by country pair in all columns. ⁺ $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Table A3: Preferential Agreements and Cross-border Patents: Sectors

	(1)	(2)	(3)	(4)
	ALL	S1	S2	S3
rta_tech_S_N	0.208 (0.049)**	0.266 (0.081)**	0.174 (0.054)**	0.236 (0.073)**
rta_tech_S_S	-0.071 (0.240)	0.265 (0.371)	-0.252 (0.379)	0.205 (0.317)
rta_tech_N_N	0.214 (0.030)**	0.156 (0.043)**	0.174 (0.040)**	0.250 (0.046)**
rta_tech_N_S	0.081 (0.041) ⁺	-0.037 (0.118)	0.069 (0.055)	0.145 (0.080) ⁺
rta_notech_S_N	-0.791 (0.538)	-0.402 (0.480)	-0.463 (0.782)	-1.313 (0.577)*
rta_notech_S_S	-0.210 (0.273)	-1.027 (0.677)	-0.212 (0.339)	0.434 (0.535)
rta_notech_N_N	1.166 (0.114)**	1.314 (0.182)**	1.190 (0.137)**	0.906 (0.223)**
rta_notech_N_S	-0.162 (0.105)	-0.055 (0.154)	-0.142 (0.121)	-0.259 (0.284)
trips_S_N	0.177 (0.138)	0.321 (0.158)*	0.243 (0.160)	0.306 (0.323)
trips_S_S	0.527 (0.167)**	0.641 (0.322)*	0.500 (0.233)*	0.302 (0.264)
trips_N_N	0.198 (0.088)*	0.116 (0.131)	0.258 (0.121)*	0.126 (0.099)
trips_N_S	-0.004 (0.129)	0.236 (0.132) ⁺	-0.028 (0.142)	-0.011 (0.268)
pct_S_N	0.587 (0.296)*	0.389 (0.414)	0.885 (0.365)*	0.526 (0.838)
pct_S_S	1.374 (0.247)**	1.578 (0.303)**	1.439 (0.312)**	1.069 (0.533)*
pct_N_N	0.167 (0.061)**	0.300 (0.069)**	0.178 (0.072)*	0.135 (0.144)
pct_N_S	0.043 (0.158)	0.105 (0.253)	0.042 (0.188)	0.341 (0.543)
<i>N</i>	157054	49271	60991	48510

This table reports results for disaggregated data. The estimates are obtained from specification (20), after allowing for the effects of globalization to vary across four bilateral groups ('North to South', 'South to South', 'North to North', and 'South to North', which are based on the income classification of the World Bank. In column (1) results are presented for all manufacturing sectors at 2 digit-level of the International Standard Industrial Classification (ISIC). Column (2) presents the result for sectors 15-19. In column (3) for sectors 20 to 29. In column (4), sectors 30-37 are grouped. The dependent variable in each specification is the number of patents and the estimator is PPML. Standard errors in parentheses are clustered by country pair in all columns but . ⁺ $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.